Chapter 4: Source Assessment

Sources of nutrients to Canyon Lake and Lake Elsinore are characterized in this section. These lakes receive nutrients via three external delivery mechanisms; watershed runoff, supplemental water deliveries, and internal sources within the lakes. This section describes each of these source categories as follows:

- Watershed Runoff (Section 4.1) – Nutrients washed off from land areas in the watersheds to each lake segment; these land areas represent unique combinations of land use, jurisdiction, and subwatershed characteristics.
- Supplemental Water (Section 4.2) – Nutrients contained within supplemental water inputs to each lake; most notable being the addition of reclaimed water to Lake Elsinore by EVMWD.
- Internal Sources (Section 4.3) – Internal sources of nutrients within each lake. Mechanisms that influence the significance of these sources include physical (resuspension by wind or propeller driven turbulence or bioturbation), biological (diagenesis of externally loaded organic matter or decaying phytoplankton within the lake bottom), and chemical (diffusive flux from bottom sediments to water column). Deposition of nutrients from atmosphere directly on the surfaces of Canyon Lake and Lake Elsinore is also described in this section.

4.1 Watershed Runoff

Flow gauges are operated by the United States Geological Survey (USGS) that continuously record discharge rates at the two inputs to Canyon Lake (Salt Creek and San Jacinto River) and from San Jacinto River inflows (mostly from Canyon Lake overflow[1]) to Lake Elsinore. This data characterizes the annual volumes of runoff that reached each lake segment over the period of record. Summary statistics for each of these gauges is presented in Table 4-1.

Table 4-1. Summary Data for USGS Flow Gauges at Inflows to Canyon Lake and Lake Elsinore

Station	Upstream Drainage Area (acres)	Period of Record	Average Annual Runoff (AFY)	Historical Peak Discharge (cfs)
San Jacinto River at Goetz Road (11070365)	358,400	2000 - 2016	5,900	3,470
Salt Creek at Murrieta Road (11070465)	74,200	1983 – 1984; 2000 - 2016	5,900	2,550
San Jacinto River at Goetz Road (11070500)	462,700	1916 - 2016	11,400	16,000

Continuous flow data from these USGS gauges for the period of 2001 through 2016 was used to calibrate a watershed runoff model for the drainage areas to the lake segments (described in Section 4.1.3 below). Figure 4-1 shows runoff inflows to Canyon Lake from the San Jacinto River and Salt Creek

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[1] USGS Gauge 11070500, San Jacinto River near Lake Elsinore, is approximately 2 miles downstream of the Canyon Lake spillway and therefore includes for runoff from a small subarea (~7,000 acres) between the two lakes in addition to Canyon Lake overflows. Thus, in years when no Canyon Lake overflows occurred, there is still runoff recorded at this gauge from the San Jacinto River into Lake Elsinore

and to Lake Elsinore from San Jacinto River. Also shown in Figure 4-1 is an estimate of runoff volume retained within Canyon Lake during each wet season. Volume retention was estimated as the difference between the summed annual volume between USGS gauges upstream and downstream of Canyon Lake for years when Canyon Lake elevation data exceeded its spill water elevation of 1381.76 ft (2003-05, 2008, and 2010-11), indicating that overflows occurred. In dry years when the lake did not reach its spill elevation, outflow was assumed to be zero (2002, 2006, 2007, 2009, and 2012-14) equating to complete volume retention.

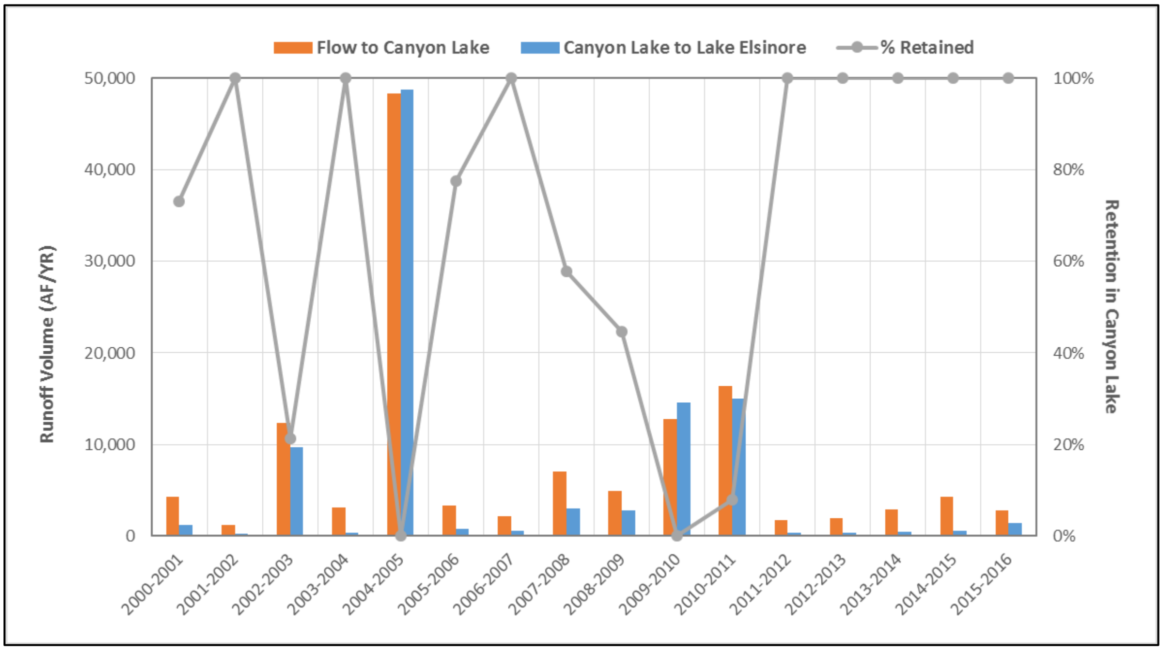

Figure 4-1
Annual Runoff Volume into Canyon Lake and Overflow to Lake Elsinore

4.1.1 Model Selection

The most significant external source of nutrients to the lakes is from rainfall driven runoff over watershed lands. To quantify the existing load of nutrients from watershed areas to the lakes, it is important to estimate the rainfall response for runoff volume (hydrology) and associated nutrient concentration (water quality). US Geological Survey (USGS) gauge stations and Task Force watershed monitoring sites provide sound, representative measurements of nutrient loads, or mass emissions, delivered to Canyon Lake and in overflows to Lake Elsinore. Given a robust set of mass emission data at key inflows to the lake segments, a model is not needed for the purpose of estimation of downstream loads in watershed runoff for current conditions. Instead, downstream mass emission data allow for reasonable parameter adjustments to fit a model of runoff volume and quality to measured data.

This source assessment does require the development of a watershed model for other important functions. The primary objective for the watershed model that was developed to support the TMDL revision is to evaluate the origin of the nutrient loads across the large upstream drainage areas. The relative contribution to downstream loads from sources is used in setting allocations and determining load reductions needed from individual sources to meet those allocations. Also, the watershed model will be useful in implementation as it allows for detailed accounting of jurisdictional loadings to each lake segment.

There are different options for modeling watershed runoff volume and quality of varying complexity, which commonly determines the required levels of expertise needed for development, calibration, and management scenario evaluation. The Loading Simulation Program in C+ (LSPC) that was used for the 2004 TMDL and again in the 2010 watershed model update represents a more complex watershed model. This model involves a deterministic simulation of rainfall and runoff including complex soil hydrology processes that govern runoff generated from pervious land areas. For water quality, nutrients are simulated by buildup or accumulation of nutrients during dry periods and washoff during rain events. Continuous simulation at the daily time-step allows for variable buildup periods between events and thus variable accumulation of pollutant available for washoff. Also, the portion of accumulated nutrients that washes off during a rainfall event to downstream waters is a function of runoff depth.

For the source assessment for Canyon Lake and Lake Elsinore watersheds, the existing LSPC tool or a potential new complex dynamic rainfall-runoff and buildup / washoff water quality model was not updated / developed for the following reasons:

- Downstream lake segments are characterized as having limited flushing and significant internal loading of bioavailable nutrients, therefore variability between events does not significantly impact the pool of bioavailable nutrients for algae. Eutrophication occurs at seasonal timescales in Canyon Lake and it is the total wet season retained nutrient load that controls the magnitude and duration of early spring algae blooms (see Linkage Analysis Section 5.X). For Lake Elsinore, bioavailable nutrients are predominantly from internal sources (see Section 4.3.1 below) and lake water quality is frequently controlled by food web dynamics with multi-decadal trends (see Linkage Analysis Section 5.X), thus variability in nutrient loads between individual storm events exerts negligible differences.

- Review of watershed monitoring data show nutrient concentrations are not related to inter-event period (number of dry days prior to an event) nor runoff volume. In fact, dynamic calibration plots presented in the TMDL and watershed model update show simulation results that have comparable central tendencies and ranges to measured data, but significant error when comparing discrete events. Thus, other processes influence watershed nutrient loads that may not be characterized by buildup / washoff dynamics.

A static model of long-term average annual runoff volume and nutrient loads, EPA's Pollutant Loading Estimator tool (PLOAD[2]), was selected to support this TMDL revision. PLOAD is a component of EPA's TMDL development framework, Better Assessment Science Integrating Point and Non-Point Sources (BASINS).[3] For this TMDL revision, PLOAD was developed outside of the BASINS environmental in a Microsoft Excel spreadsheet to allow for greater flexibility and transferability to potential end users.

The use of a static model with empirically defined parameters is scientifically defensible for this watershed because of the limited flushing in the receiving waters, long-term timescales over which eutrophication occurs, apparent complexity of watershed runoff and nutrient loading that may be

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[2] https://nctc.fws.gov/courses/references/tutorials/geospatial/CSP7306/Readings/2002_05_10_BASINS_b3docs_PLOAD_v3.pdf

[3] https://www.epa.gov/exposure-assessment-models/basins

infeasible to represent in any EPA approved, dynamic, deterministic modeling tools, and robustness of mass emission data available for all major inflow to each lake segment.

4.1.2 Establishment of Model Subareas

The first step in the watershed runoff nutrient source analysis is to define the spatial discretization for simulation of rainfall driven runoff and associated washoff of nutrients. The selected modeling approach, comparable to PLOAD, is a spatially lumped parameter model. This means that commonality of key parameters, not geography, is used to define distinct subareas. Watershed runoff simulations were developed for land areas with common land use, jurisdiction, and subwatershed zone, referred to as model subareas. Figure 4-2 shows the geographic distribution of these three defining attributes for the entire watershed to Canyon Lake and Lake Elsinore (a plot size version of this figure is attached in electronic form).

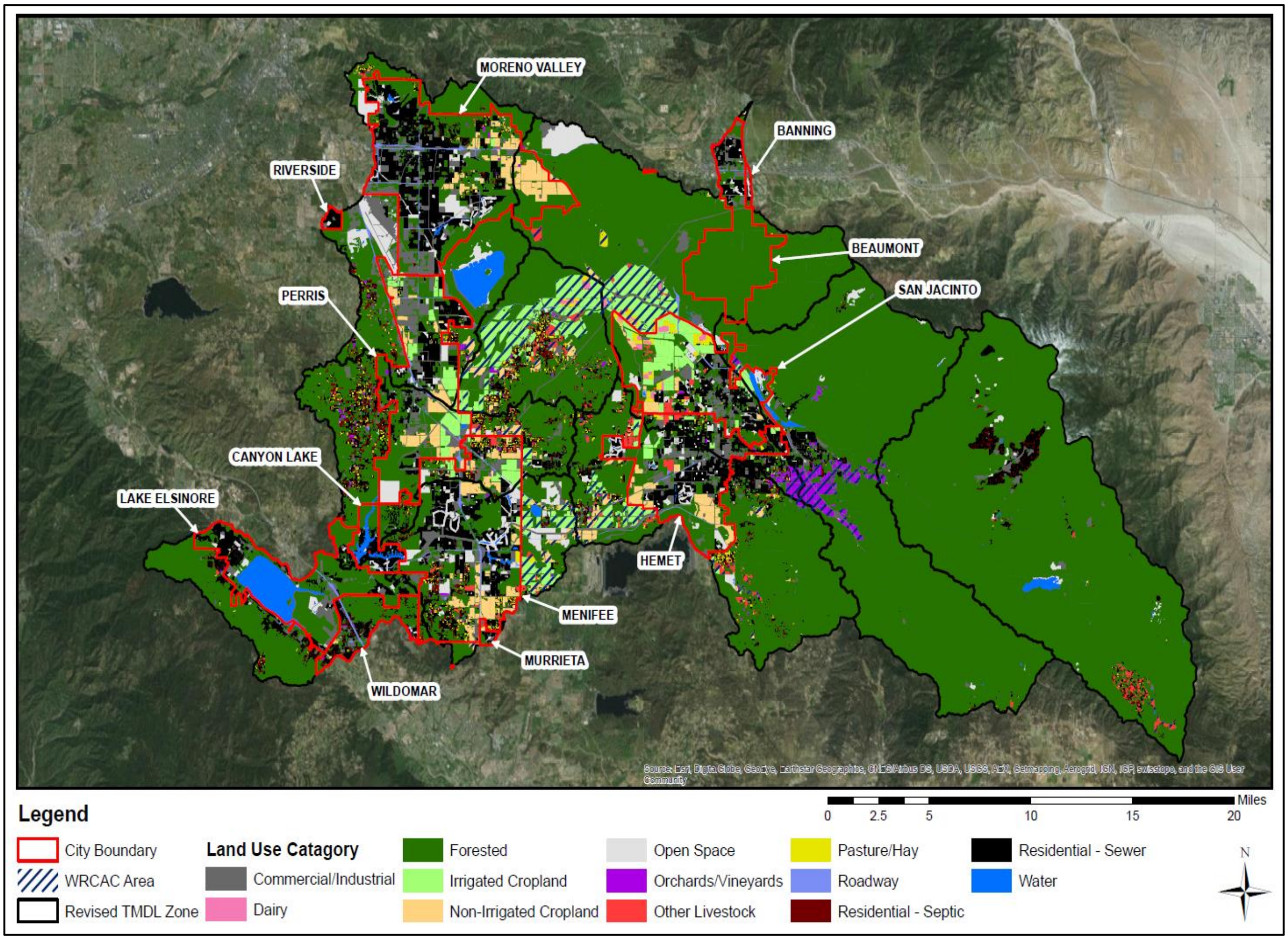

Figure 4-2
Map of subwatershed zones, jurisdictions, and land use for development of watershed model subareas

Hydrology and water quality modeling is performed separately for each model subarea. Figure 4-3 shows the interconnectivity of model subareas and conveyance within receiving waters. Respectively, the green and red boxes along the outer perimeter represent agricultural and urban jurisdictional groups within each subwatershed zone. Within each of these watershed elements of this schematic, one or more land uses may exist. In total, there are over 500 distinct model subareas developed to support source assessment and development of allocations. These model subareas are not geographically contiguous, but rather they are spatially lumped portions of drainage area with common parameter sets. For example, a single model subarea exists to represent all commercial/industrial land area within the City of Moreno Valley within subwatershed zone 5. Appendix A provides a tabular summary of each model subareas and reports important characteristics used for parameterizing the water runoff model.

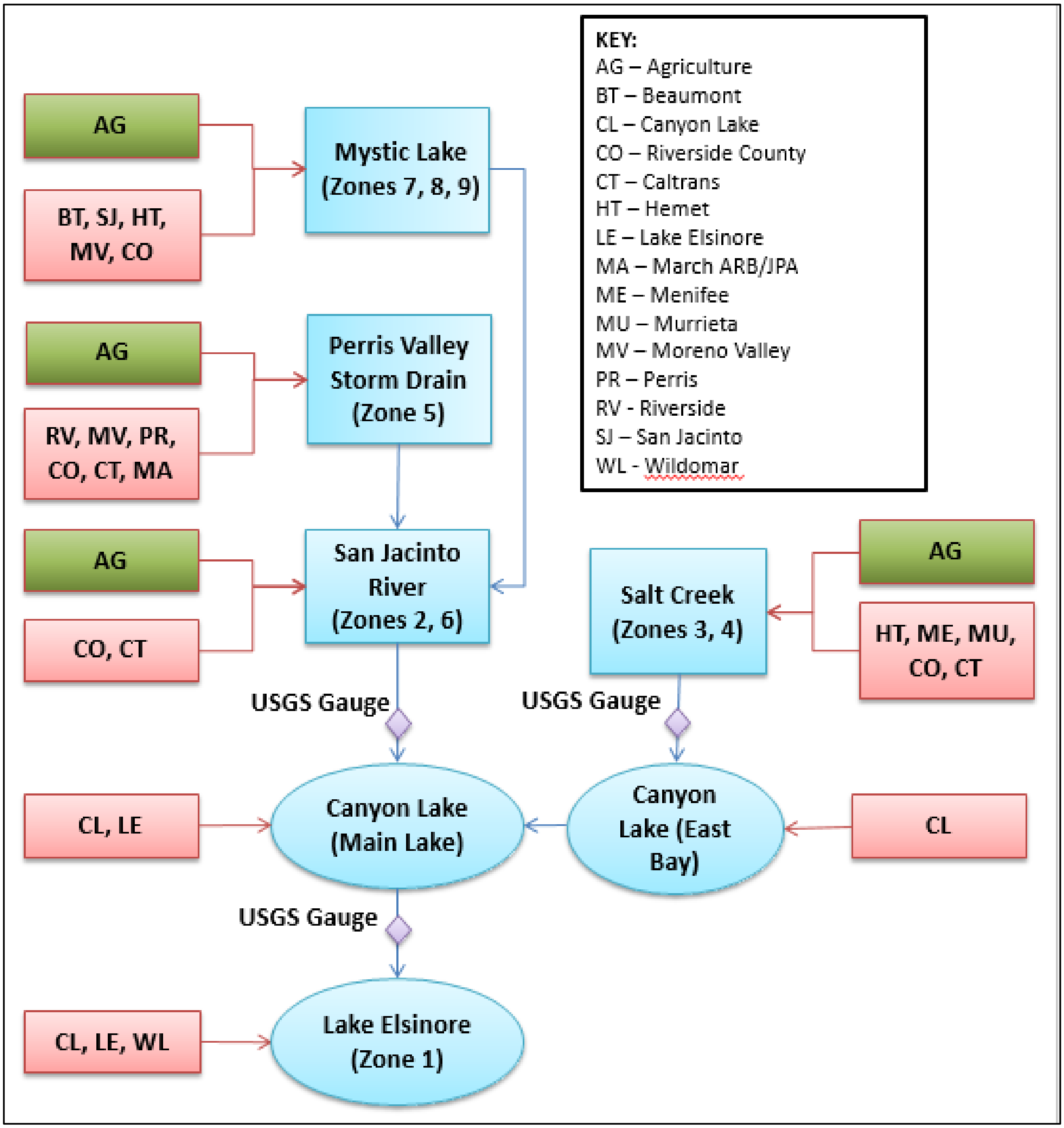

Figure 4-3
Schematic of watershed runoff model

The schematic also shows how runoff is routed from model subareas to receiving waters. Subwatershed zone delineations were developed based on this routing, as indicated in each of the blue receiving water elements. Some model subareas drain directly to one of the three TMDL lake segments; Canyon Lake Main Lake and East Bay, and Lake Elsinore. Other model subareas are routed through the San Jacinto River, Perris Valley Channel, or Salt Creek prior to reaching a TMDL lake segment. The position of Mystic Lake as an important impoundment to be accounted in the source assessment is also shown in the schematic. Model subareas draining to Mystic Lake are treated differently as discussed in Section 4.1.3.4 below.

For this TMDL revision, several subwatershed boundary revisions were incorporated to update the boundaries used in the 2004 TMDL and TMDL model update in 2010 (Figure 4-4). Hatched areas in Figure 4-4 show where boundaries are revised and labels indicate the change from the 2004 TMDL to this TMDL revision. The revision are summarized below:

- Mystic Lake tributary area correction – The drainage area to Mystic Lake, subwatershed zones 7, 8, and 9 in the 2004 TMDL, was re-evaluated by WRCAC to support the TMDL revision. An elevation map of the region combined with knowledge of surface features was used to develop a new, technically correct delineation of the area tributary to Mystic Lake[4]. Revisions are shown in green (drainage area taken out of Zone 7) or purple (drainage area put into Zone 7) hatching in Figure 4-4. The revisions included removal of a large drainage area near the bend of the San Jacinto River that is not tributary to Mystic Lake; instead this area contributes runoff to Canyon Lake in most hydrologic years. Also, modification to the boundary near North Warren Rd in the vicinity of the Colorado River aqueduct. In total, the changes amount to a net reduction of ~5,000 drainage acres to subwatershed zone 7, and a net increase in the same amount for subwatersheds downstream of Mystic Lake.
- Local Canyon Lake tributary area to East Bay / Main Lake – Subwatershed zones 2 and 3 in the 2004 TMDL and 2010 watershed model update represent the downstream portions of San Jacinto River and Salt Creek, respectively. However, downstream of the USGS gauges / watershed monitoring stations, the boundary between these subwatershed zones does not properly delineate areas draining directly to the Main Lake of Canyon Lake (from the San Jacinto River) versus draining directly to the East Bay of Canyon Lake (from Salt Creek). The blue hatched area in Figure 4-4 indicate the areas that were revised to properly reflect drainage to East Bay.

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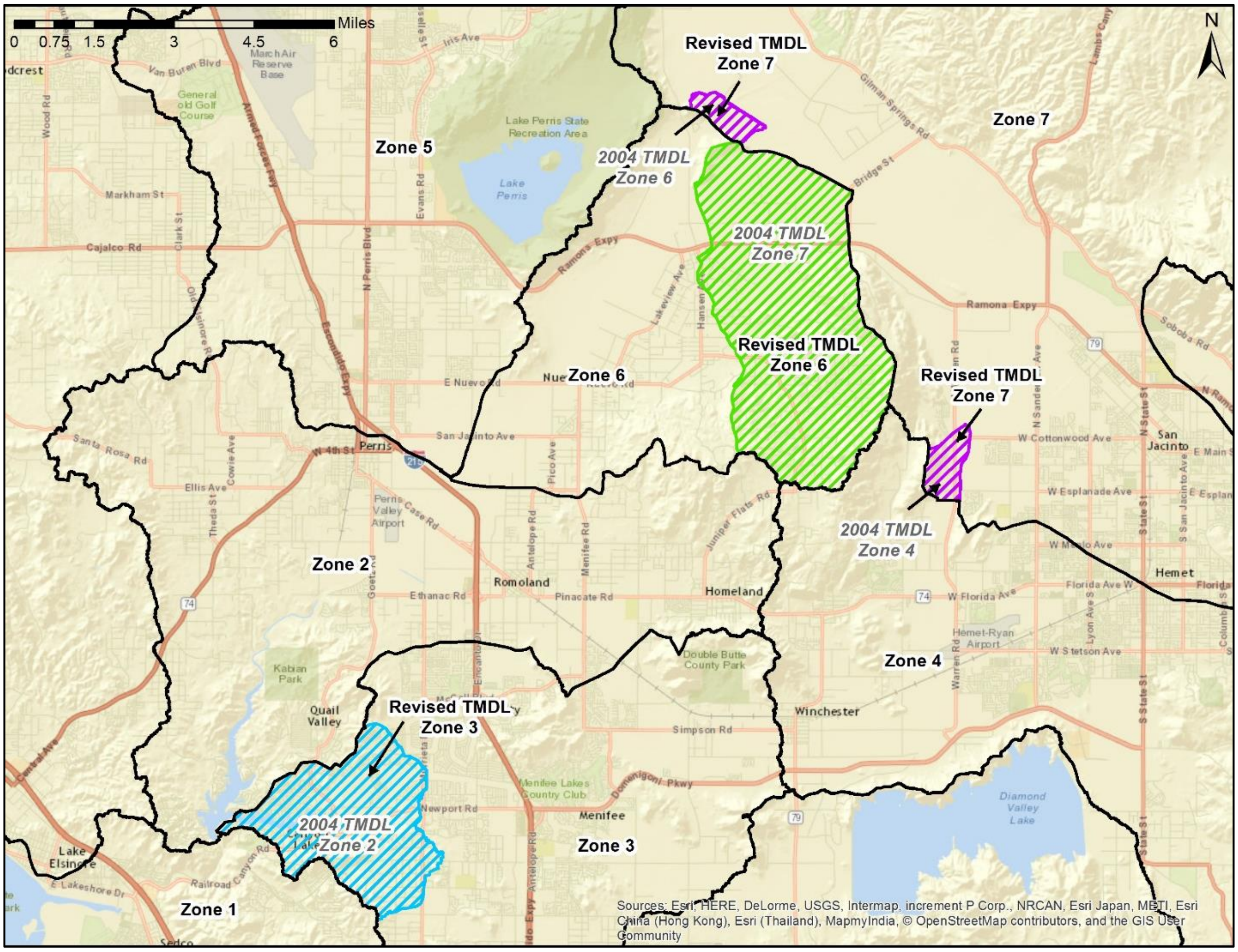
[4] CDM Smith. Technical Memorandum; Update to San Jacinto Watershed Zone Delineation, October 31, 2013.



Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 4-4
Map of revisions to subwatershed zonal boundaries

4.1.3 Hydrology

A static model was developed within a Microsoft Excel spreadsheet to simulate the volume of average annual runoff in model subareas as a result of rainfall, presented in the equation below:

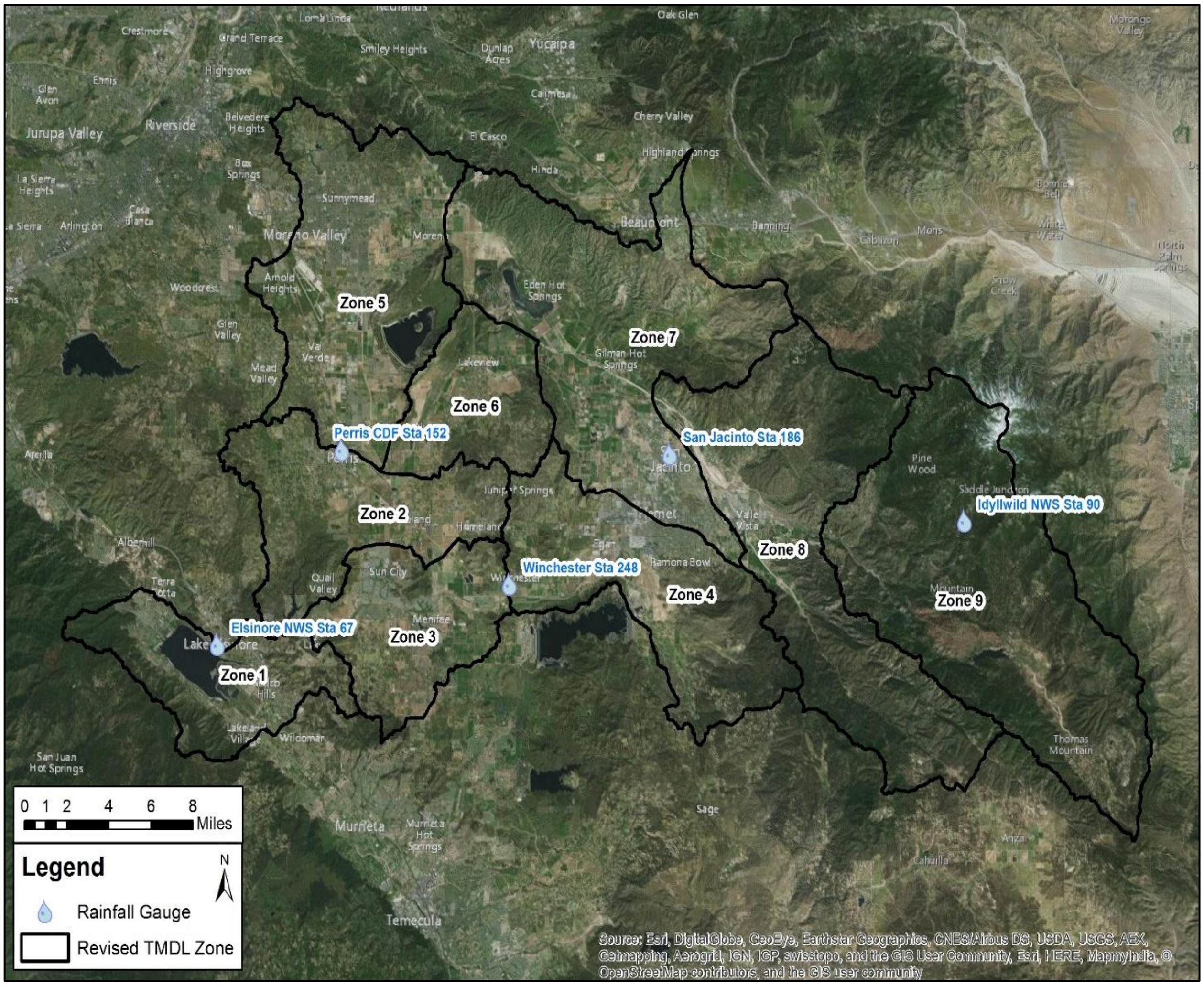
$$Q_{annual} = Precip_{annual} * RC$$

where,
Q_{annual} = annual flow volume
$Precip_{annual}$ = average annual rainfall depth
RC = runoff coefficient

This hydrologic method is used in an EPA approved public domain watershed model PLOAD. The following sections describe the methods used to develop the hydrologic model for the watersheds that drain to Canyon Lake and Lake Elsinore.

4.1.3.1 Precipitation

Precipitation input data for the model was extracted from RCFC&WCD rainfall stations distributed throughout the watershed (Figure 4-5). Table 4-2 presents long-term average annual rainfall from these stations, which are assigned to represent specific subwatershed zones. For subareas above Mystic Lake (i.e., subwatershed zones 7-9), rainfall from the San Jacinto Station 186 was used to represent drainage areas with elevations below 3000 feet and rainfall from the Idyllwild Station 90 was used to represent areas with elevation greater than 3000 feet. Table 4-2 provides average annual rainfall for different periods representing the full period of record at each station for comparison with the selected subsets for model calibration and allocation setting. The period used for model calibration (2000-2015) coincides with the period of record for USGS flow gauges at the two primary inflows to Canyon Lake; San Jacinto River at Goetz Road (USGS Station 11070365) and Salt Creek at Murrieta Road (USGS Station 11070465). The allocation setting period of 1948-2015 was selected as the period with continuous rainfall records with no missing data from all of the stations used in the watershed model. The average annual rainfall from this period is very similar to the average for the full period of record for each station.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

Figure 4-5

Map of rainfall stations used for long-term rainfall depth inputs to the watershed model

Table 4-2. Rainfall Station Summary Statistics and Linkage to Model Subwatersheds

Station	Period of Record	Period of Record Average Rainfall (in/yr)	1948-2015 Average[1] Rainfall (in/yr)	2000-2015 Average[2] Rainfall (in/yr)	Subwatershed Zone
San Jacinto Sta 186	1903 – Present	12.7	12.0	10.0	7,8,9 (below 3000')
Elsinore NWS Sta 67	1896 - Present	12.1	11.4	10.0	1
Perris CDF Sta 152	1910 – Present	10.5	10.3	8.9	2,5,6
Winchester Sta 248	1940 - Present	10.9	10.8	9.4	3,4
Idyllwild NWS Sta 90	1929 – Present	25.8	25.7	22.8	7,8,9 (above 3000')

1) Average annual rainfall used to estimate runoff volume for determining existing and allowable loads for TMDL
2) Average annual rainfall used to fit watershed runoff model to measured data at USGS gauging stations

4.1.3.2 Runoff Coefficient

A runoff coefficient (RC) is a factor to express the ratio of rainfall to surface runoff. Simple hydrologic modeling methods, such as the Rational Method and derivations thereof, estimate the runoff coefficient as a function of watershed imperviousness. The connectivity of impervious land cover to MS4 inlets is an important consideration, especially in newer developments that employ low-impact development (LID) site designs that strive to disconnect impervious areas to prevent runoff reaching surface waters. Similarly, lower density residential land use is characterized by unpaved or partially paved walkways and driveways that have less directly connected impervious area (DCIA). Given this, for the Canyon Lake and Lake Elsinore watersheds, an exponential function was selected to estimate runoff coefficients that best relates increased connectivity with increased imperviousness (Bochis-Micu and Pitt, 2005[5]). Two factors are included in the exponential function, including; 1) a watershed-wide estimate of runoff / rainfall ratio for pervious lands (*a*), and 2) exponent factor (*b*) for imperviousness (IMP).

$$RC = a * e^{(b*IMP)}$$

An initial parameter estimate of *a* = 0.05 was selected for model development based on typically measured runoff ratios for varying levels of imperviousness in 47 hydrology studies from across the nation (Schueler, 1987[6]). Pervious area runoff is variable and influenced by factors such as slope, soil health, and vegetative cover fraction, which can vary between watersheds. Thus, this value was allowed to be adjusted within +/- 50 percent (from 0.0 to 0.1) during model calibration. Bochis-Mitu and Pitt, (2005)[4] suggest that the coefficient in the exponent be set to meet an assumption of 90 percent runoff ratio for a completely impervious watershed. Thus, for the exponent coefficient *b*, a value of 2.3 was set

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[5] Bochis-Micu, Celina, and Robert Pitt. 2005. Impervious Surfaces in Urban Watersheds, Proceedings of the 78thAnnual Water Environment Federation Technical Exposition and Conference in Washington, D.C., Oct. 29 – Nov. 2, 2005

[6] Schueler, T. 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practices*. MWCOG. Washington, D.C.

as default when $a = 0.05$. These two factors are the primary variables used for fit results of the PLOAD model for the TMDL revision to approximate measured annual runoff volumes.

The Multi-Resolution Land Characteristics Consortium (MRLC)[7] maintains a national map of impervious surfaces with a spatial resolution of 30 meters, most recently updated in 2011[8] (Homer et al., 2015). Imperviousness within the watersheds to Canyon Lake and Lake Elsinore was extracted from this national map and used for estimating runoff coefficients from model subareas with the above equation (Figure 4-6).

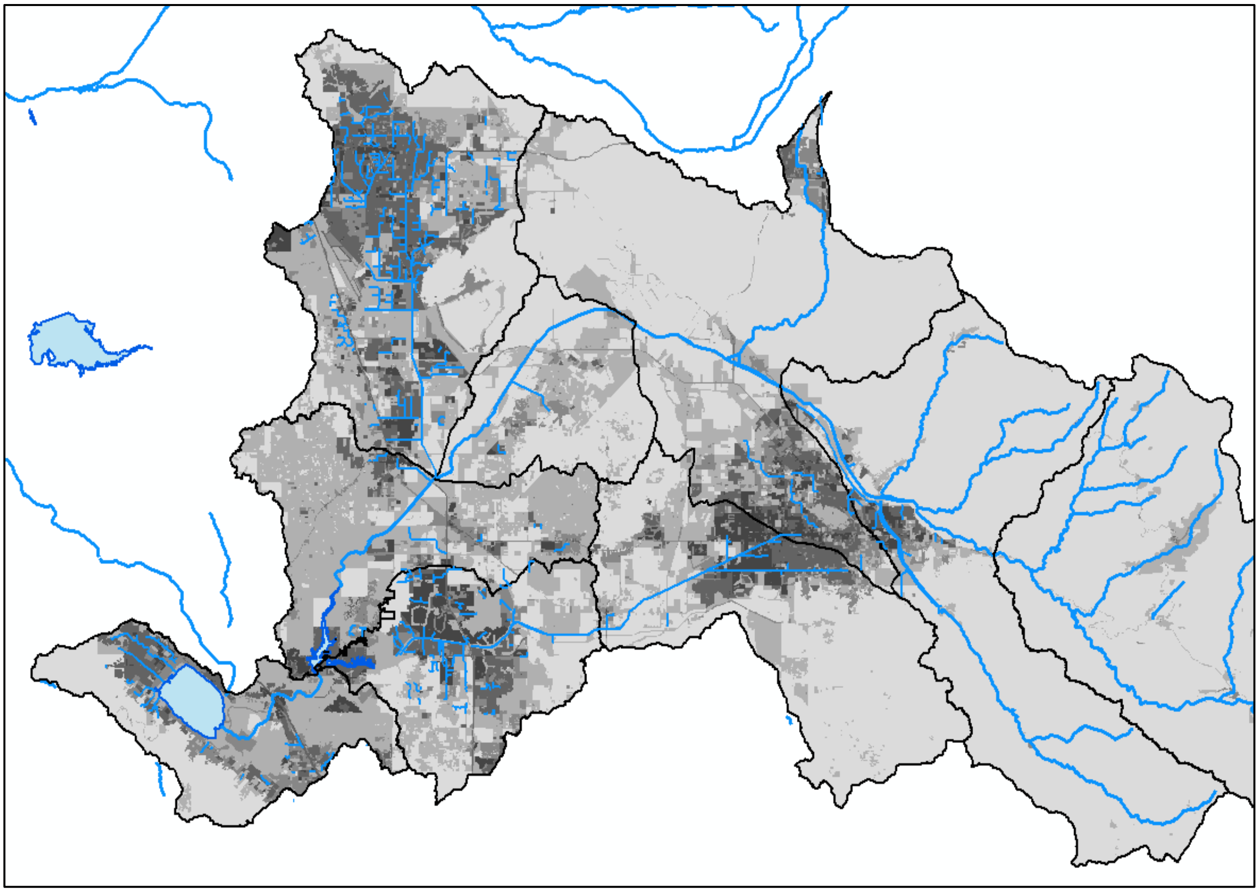

Figure 4-6
Imperviousness in the Canyon Lake and Lake Elsinore Watersheds

4.1.3.3 Downstream Retention in Unlined Channels

Not all rainfall that runs off into a surface water reaches Canyon Lake because of recharge that occurs in bottom sediments of unlined channel bottoms. Figure 4-7 shows the unlined channel bottom segments throughout the watershed where downstream retention and groundwater recharge of runoff is known

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[7] http://www.mrlc.gov/

[8] Homer, C.G., Dewitz, J.A., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N.D., Wickham, J.D., and Megown, K., 2015, Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. *Photogrammetric Engineering and Remote Sensing*, v. 81, no. 5, p. 345-354

to occur. The major unlined channel segments that infiltrate upstream runoff include Salt Creek, San Jacinto River, and Perris Valley Channel.

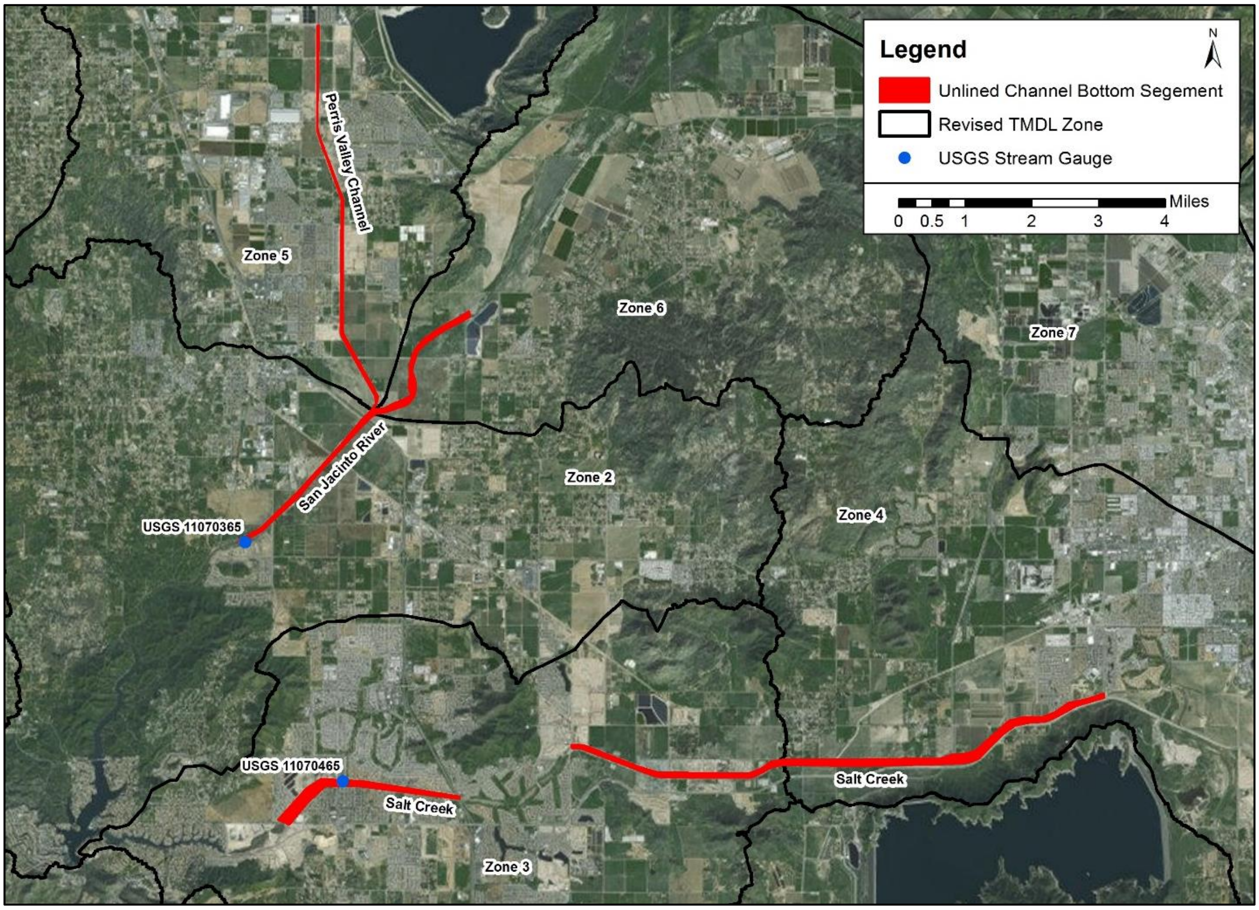

Figure 4-7
Unlined Channel Bottom Segments in the Canyon Lake and Lake Elsinore Watersheds

To estimate the annual loss of runoff within these channel bottoms, a separate hydrologic data analysis was completed. The potential daily infiltration volume into the channel bottom segments was approximated from typical percolation rates for soils and the extent of the unlined channel bottom (Table 4-3). Daily runoff data from the period of record at the inflows to Canyon Lake (2000 – 2016) was evaluated to estimate the number of days when channel bottoms may have actively infiltrated upstream runoff. This was accomplished by assuming infiltration within unlined channel bottoms only occurred on days when the nearest downstream gauged flow exceeded a threshold indicative of wet weather conditions. The final column of Table 4-3 presents the estimated average annual yield of infiltrated runoff in each channel bottom segment

This estimated annual recharge volume (AFY) in Table 4-2 for each unlined channel bottom segment is converted into a depth of runoff from the upstream drainage areas within that subwatershed zone: (a) subwatershed zone 5 to Perris Valley Channel; (b) subwatershed zone 6 to San Jacinto River; and (c) subwatershed zone 4 to Salt Creek. The estimated depth of watershed runoff retained in channel bottoms (D_{ret}) is added into the hydrologic model for subareas in these zones as follows:

$$Q_{annual} = (Precip_{annual} * RC) - D_{retention}$$

Table 4-3. Unlined Channel Bottom Segments and Estimated Average Annual Runoff Retained from Upstream Drainage Areas

Channel	Bottom Area (acres)	Recharge Rate (ft/day)	Downstream Flow Threshold (cfs)[1]	Number of Recharge Days (2000-2015)	Estimated Annual Recharge (AFY)
San Jacinto River	111	0.1	20	257	150
Perris Valley Channel	222	0.1	20	257	300
Salt Creek	600	0.3	10	224	2800

1) Downstream flow gauges for San Jacinto River and Perris Valley Channel is San Jacinto River at Goetz Rd (Sta 11070365) and Salt Creek at Murrieta Rd (Station 11070465) for Salt Creek. The period of record for these gauges is 2000-2016.

4.1.3.4 Influence of Mystic Lake

Watershed runoff in the upper San Jacinto River is captured in Hemet Lake within the National Forest and ultimately Mystic Lake, a large shallow depression in the San Jacinto valley (Figure 4-8). Mystic Lake has a storage capacity of approximately 17,000 AF, which is sufficient to retain all runoff from the upper watershed in most years. In addition, runoff is captured for water supply at Lake Hemet and groundwater recharge by EMWD in a series of spreading grounds (Figure 4-8). In years when Mystic Lake's storage volume is filled, large volumes of runoff may be delivered to Canyon Lake from the upper watershed, i.e. subwatershed zones 7-9. Mystic Lake overflows are known to have occurred in the 1993-94, 1995-96, and 1998-99 water years[9], but not in subsequent wet years when flow gauge data showed no overflows occurred (notable being the 2004-2005 season). Given this, there is no downstream flow data for inflows to Canyon Lake during any overflow year (USGS gauge installed in 2000 after most recent known overflow in 1998). Thus, runoff from model subareas in subwatershed zones 7-9 is assumed to be entirely retained in Mystic Lake for the calibration of runoff for the 2000-2016 period. Runoff and associated nutrient loads that may potentially occur during future Mystic Lake overflows are estimated as described in this section.

Rainfall stations in the region have actively collected data for 112 years at RCFC&WCD Station 186 San Jacinto and 86 years at RCFC&WCD Station 90 Idyllwild (see Table 4-2 above). These two rainfall stations are used to estimate runoff in model subareas within subwatershed zones 7, 8, and 9 with San Jacinto rainfall used for subareas below 3000' elevation and Idyllwild rainfall used for subareas above 3000' elevation. The watershed model was used to conduct a time series analysis for years with concurrent rainfall data at both of these stations (1929 – 2016). The pervious area runoff coefficient was adjusted to account for significant attenuation in these subwatershed zones with retention in Lake Hemet and EMWD groundwater recharge basins that capture surface runoff from diversions in the upper San Jacinto River. The final parameters of a=0.034 and b=2.3 were determined to meet the conditions that would generate overflows in water years 1993-94, 1995-96, and 1998-99, and not in water year 2004-05 based on a reservoir water budget analysis described below. Modeled estimates of annual runoff over this period from San Jacinto River into Mystic Lake are plotted in Figure 4-9.

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[9] http://www.sawpa.org/wp-content/uploads/2012/05/2015-8-11-Presentations-3.pdf

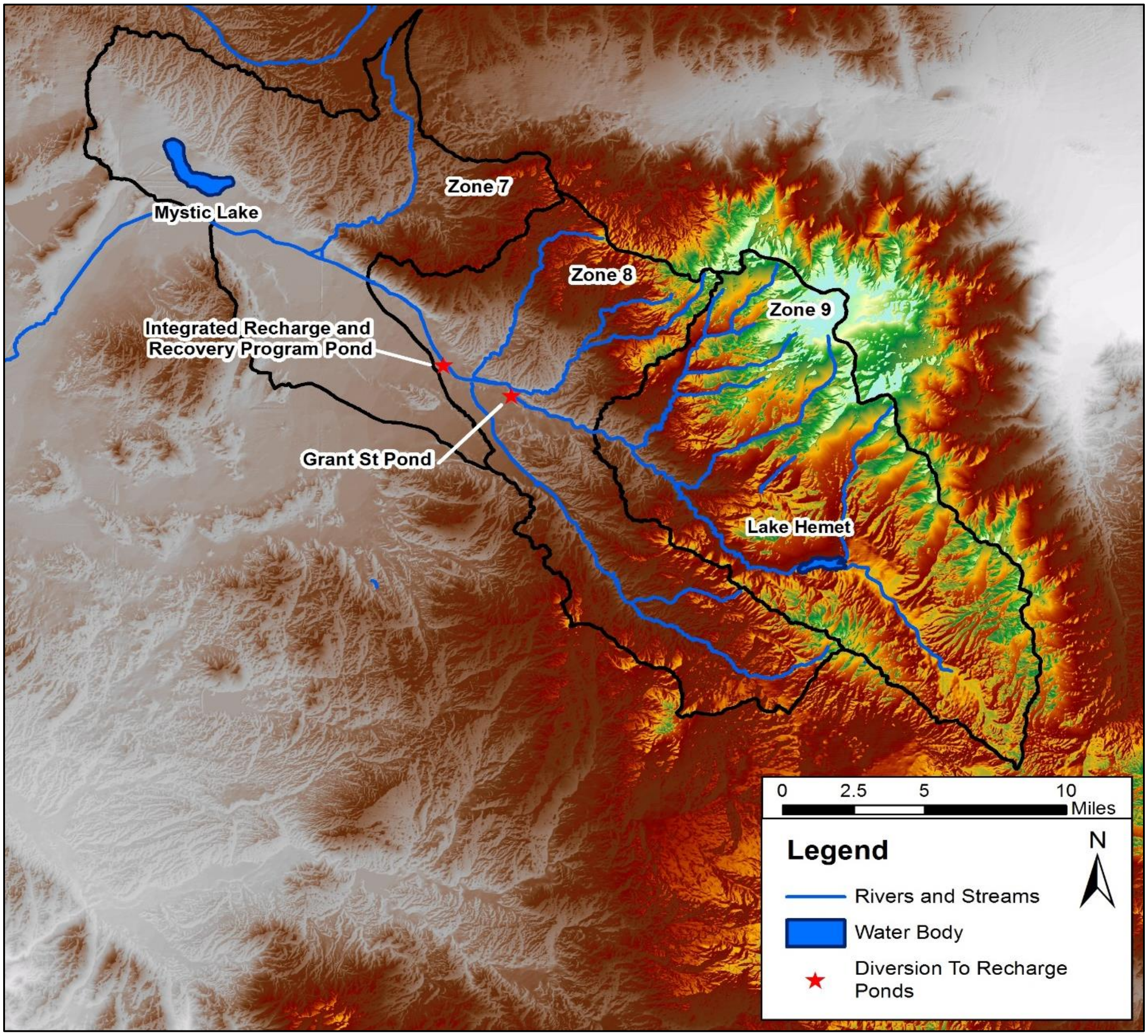

Figure 4-8
Drainage area upstream of Mystic Lake

A reservoir water budget analysis after Gilbert (1970)[10] was developed to approximate the volume of overflow in a given wet season (O_i) from Mystic Lake to Canyon Lake by estimating key water budget components of runoff inflow (*R*), available storage capacity (*S*), and dry season evaporative losses (*E*), as follows:

$$O_i = R_i - (S_{MAX} - S_i)$$

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[10] Gilbert, C. R., 1970. Water loss studies of Lake Corpus Christi, Nueces River Basin, Texas 1949-1965: Texas Water Development Board Report 104.

$$S_i = R_{i-1} + S_{i-1} - E_{i-1} - O_{i-1}$$

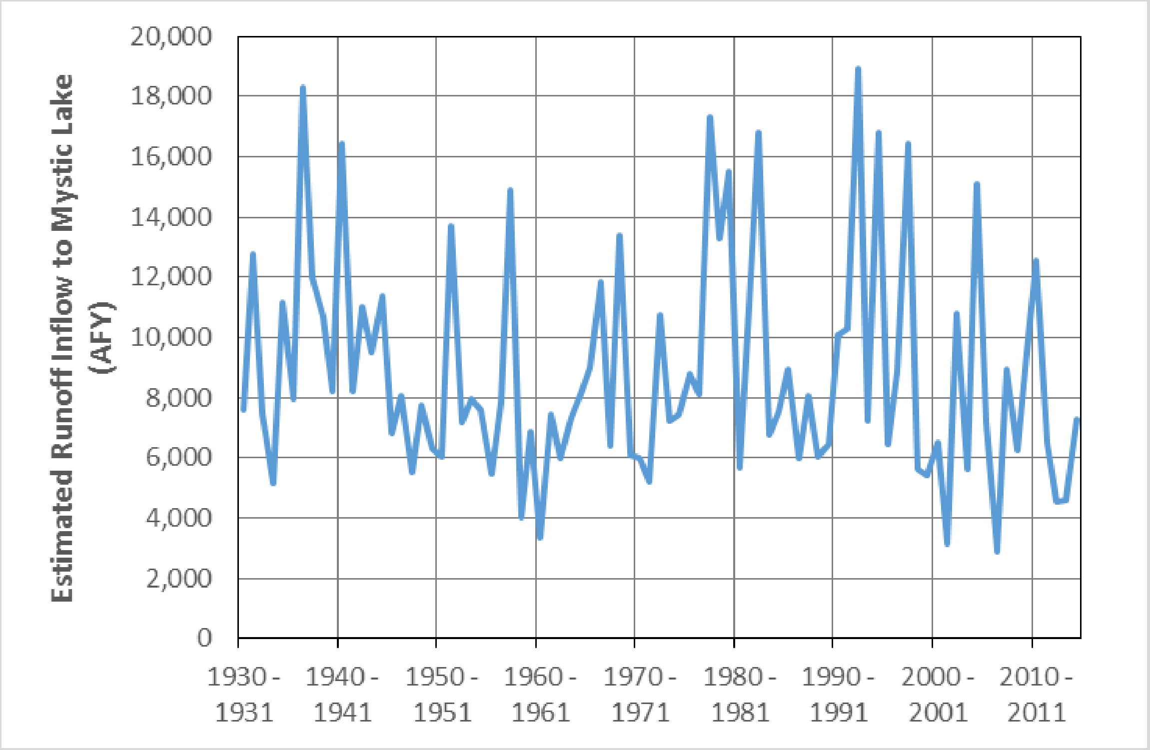

Figure 4-9
Modeled runoff inflow to Mystic Lake

Subsidence of land within the Mystic Lake basin bottom is continually adding an estimated 200 AF of storage capacity each year, as documented with review of historical bathymetric maps (Morton, 2015)[11] Looking forward, an estimated 5,000 additional AF of storage capacity may exist in 2040. To account for this future rise in storage capacity, the water budget analysis was developed with an assumed maximum storage capacity (S_{MAX}) of 22,000 AF, greater than the current estimate of 17,000 AF.

The results predict that overflows from Mystic Lake to Canyon Lake may have occurred in 18 of 86 years since 1929, with the most recent during the 1997-98 wet season (see Appendix B for tabular outputs). More important than the frequency of overflows, is the volume of runoff that reaches Canyon Lake from the upper watershed. The reservoir routing analysis predicted that an average of ~4,500 AFY in overflow years and a range of less than 500 AFY to over 9,000 AFY (Figure 4-10).

The water budget analysis showed that storage (S_{i-1}) was close to maximum capacity (S_{MAX}) in wet seasons leading up to each overflow year. Thus, overflow volume is largely the amount of runoff in excess of evaporative losses occurring during the dry season that occurs during consecutive years of above average rainfall. Comparing the estimated overflow of ~900 AFY to the total runoff volume from the upper watershed for the 86-year simulation period of ~9,000 AFY suggests that 10 percent of long term runoff from subwatersheds 7-9 may reach Canyon Lake. Thus, a factor of 0.10 is applied in the

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[11] http://ngmdb.usgs.gov/Prodesc/proddesc_78686.htm

model to estimate long term average runoff and associated pollutant loads from the upper watershed to the Main Lake of Canyon Lake

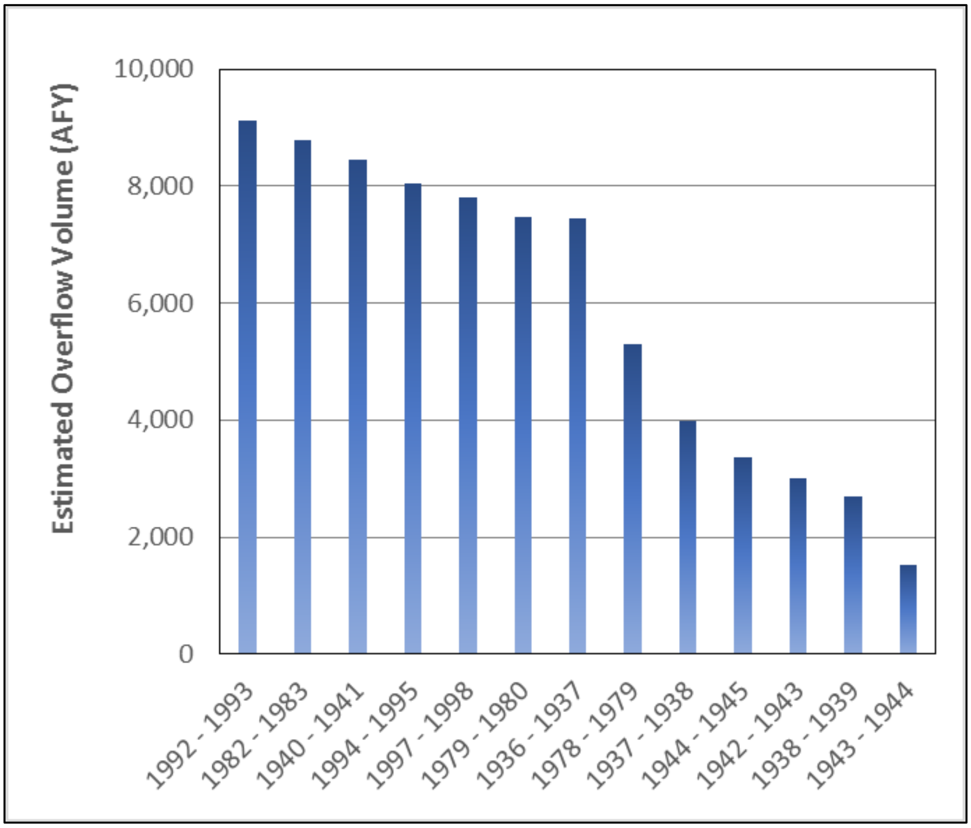

Figure 4-10
Modeled overflow volume from Mystic Lake to Canyon Lake (years not shown did not result in a spill)

4.1.3.5 Hydrologic Model Results

Comparisons were made between measured and modeled average annual runoff delivered to Canyon Lake from model subareas upstream of the USGS gauges on San Jacinto River at Goetz Road and Salt Creek at Murrieta Road. To make this comparison it was necessary to do an additional delineation for subwatershed zones 2 and 3 downstream of these gauges, in order to discount modeled runoff from portions of these subwatersheds that are downstream of the San Jacinto River at Goetz Road and Salt Creek at Murrieta Road USGS gauge stations. The ungauged portions comprise ~25,000 acres and amount to ~16 percent of the total drainage area to Canyon Lake below Mystic Lake. These ungauged areas include land areas that drain directly to the shoreline of Canyon Lake and a large tributary referred to as Meadow Brook (Figure 4-11).

The factors used to estimate runoff coefficients as a function of subarea imperviousness were adjusted (a=0.065, b=2.3) to fit modeled long-term average annual runoff volume to averages from the USGS gauges (Figure 4-12). Fitting a static condition of annual average runoff volume allows for a very close fit of model estimates to measured data by attenuating the natural dynamic variability.

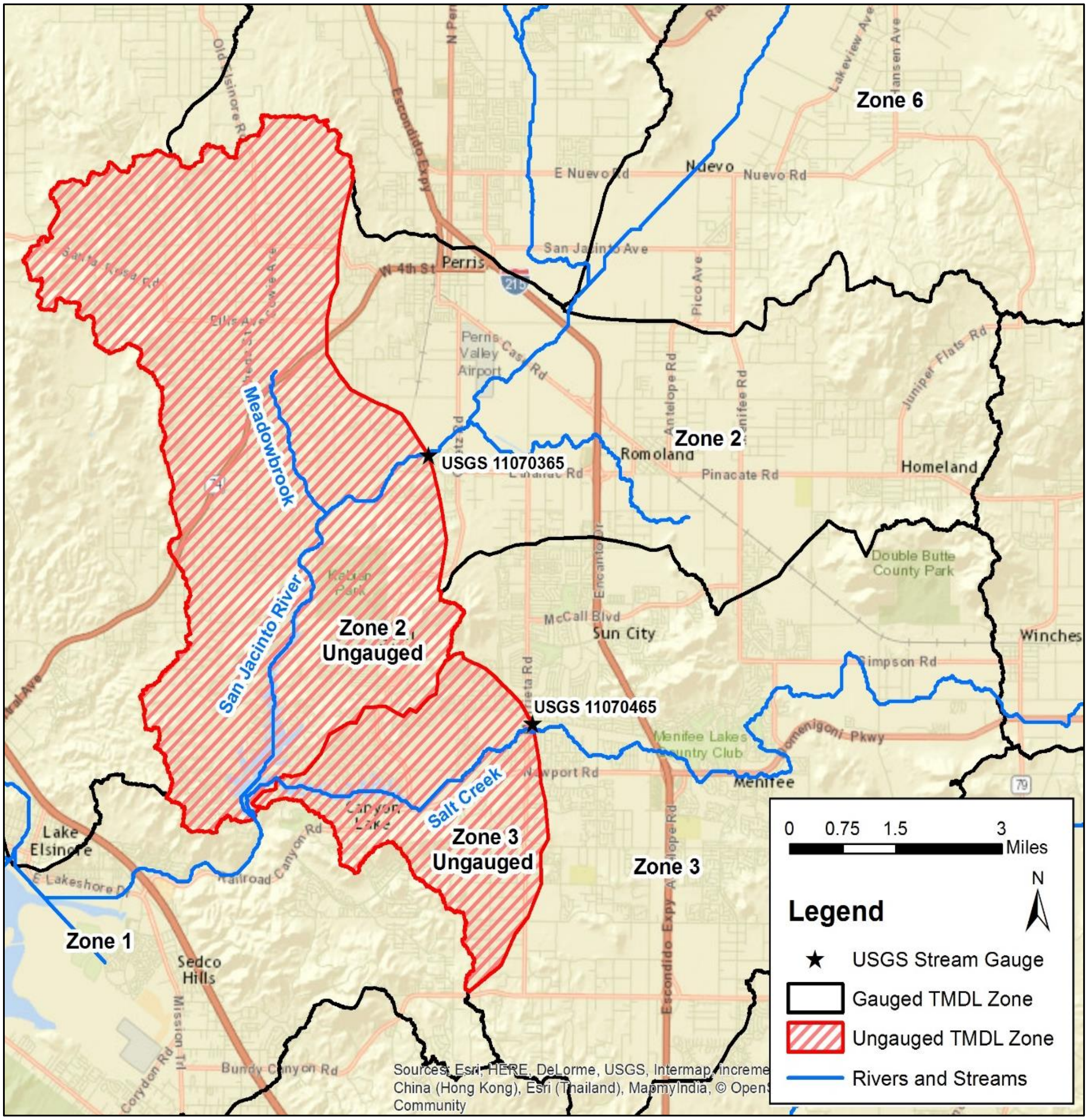

Figure 4-11
Drainage areas downstream of USGS gauge stations not included in comparison of modeled to measured runoff volume

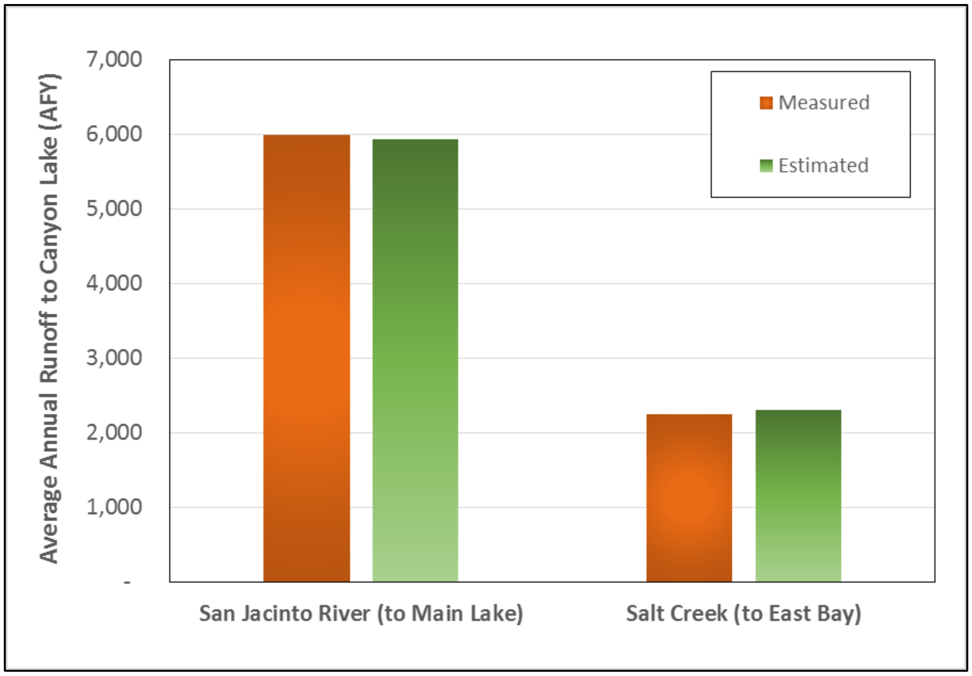

Figure 4-12
Comparison of modeled and measured average (2000-2015) annual runoff volume for primary inflows to Canyon Lake

Average annual runoff volume was estimated using long-term average rainfall based on the entire period of concurrent rainfall data at RCFC&WCD stations of 1948-2015 (shown in Table 4-2 above). Results shown in Table 4-4 represent the estimated average annual volume of runoff delivered to Canyon Lake, Main Lake and East Bay, and Lake Elsinore from all watershed lands. These results account for losses in unlined channel bottom segments and include the long term average of runoff overflow volume (computed including years with zero values) from drainage areas upstream of Mystic Lake. The runoff inflow volume shown for Lake Elsinore is for the local drainage and does not include overflows from Canyon Lake.

Table 4-4. Estimated Long-Term (1948-2015) Average Runoff Volume Delivered to Lake Segments from All Watershed Lands

Average Annual Runoff Inflows to Lakes (AFY)	San Jacinto River (to Main Lake of Canyon Lake)	Salt Creek (to East Bay of Canyon Lake)	Local Lake Elsinore	Total
Modeled - Current Land use	11,310	3,585	3,002	17,897

4.1.4 Water Quality

The preceding section describes a static model for estimating volume of watershed runoff generated from different model subareas that is delivered to each lake segment. Watershed runoff contains nutrients, total phosphorus and total nitrogen, that are conveyed through drainage features to the downstream lake segments. In wet years, the greatest source of nutrients to the lakes segments comes from the watershed with runoff. The following sections describe types of nutrient sources in the model subareas, the concentration of nutrients washed off from different land use types, and the total load of nutrients delivered to the lake segments as external loads in watershed runoff.

4.1.4.1 *Sources of Nutrients in Watershed Runoff*

Specific sources of nutrients that may be available for washoff with runoff are listed below:

- Trash
- Fertilizers
- Green waste
- Pet waste
- Septic system failure
- Detergents
- Construction sites
- Erosion of exposed soils

The source assessment estimates total nitrogen and total phosphorus washoff from model subareas for generalized land use categories in drainage areas upstream of Canyon Lake (Main Lake and East Bay) and Lake Elsinore (local drainage downstream of Canyon Lake) (Table 4-5). Detailed land use distributions by subwatershed zone and jurisdiction are provided in Appendix A.

Table 4-5. Distribution of Land Use (Acres) in Areas that Drain to Canyon Lake and Lake Elsinore

Land Use	San Jacinto River (to Main Lake)[1]	Salt Creek (to East Bay)	Local Lake Elsinore	Total
Commercial / Industrial	18582	5157	1854	25594
Dairy	812	0	4	816
Forested	262484	41487	17472	321444
Irrigated Cropland	16446	3800	0	20246
Non-Irrigated Cropland	8085	5278	22	13386
Open Space	9240	4287	544	14071
Orchards / Vineyards	3953	322	56	4330
Other Livestock	2179	1120	30	3329
Pasture / Hay	2473	646	53	3173
Roadway	2014	785	240	3039
Water	3717	427	3183	7327
Residential – Septic [2]	2601	1008	254	3863
Residential – Sewer	41623	17450	6652	65726
Total	374210	81768	30365	486342

1) Acres shown include drainage areas upstream of Mystic Lake in subwatersheds 7-9

2) Residential land use on septic systems was approximated by intersecting GIS layers of Riverside County parcels containing a septic tank with 2014 land use areas mapped as low-density residential

4.1.4.2 *Nutrient Loading to Lake Segments*

The existing loads to Canyon Lake and from Canyon Lake to Lake Elsinore can be approximated from historical flow and water quality data from the two inputs to Canyon Lake (Salt Creek and San Jacinto River) and from San Jacinto River inflows to Lake Elsinore. The gauges are downstream of the majority of drainage area to the lake segments, although adjustments are made in the modeling approach to account for ungauged drainage areas, as described in the following section 4.1.4.3. The concentration of nutrients for inflows to and outflows from Canyon Lake have been monitored during 25 storm events between 2008 and 2016 by the Task Force. Data are sufficiently robust from these watershed monitoring activities to be considered representative of long term averages and to characterize most of the expected variability associated with seasonality and magnitude of storm events. Event based summary data is presented in Table 4-6.

Table 4-6. Average Storm Event Nutrient Concentrations from Watershed Monitoring Sites

Event	Date	San Jacinto River at Goetz Rd		Salt Creek at Murrieta Rd		Canyon Lake Overflow		Cranston Guard Station	
		TP (mg/L)	TN (mg/L)	TP (mg/L)	TN (mg/L)	TP (mg/L)	TN (mg/L)	TP (mg/L)	TN (mg/L)
1	1/11/2001	0.62	7.03	0.32	4.83				
2	1/26/2001	0.21	10.60	0.20	5.80				
3	2/13/2001	0.49	5.50	0.28	3.24				
4	2/25/2001	0.41	4.98	0.44	3.40	0.17	2.70		
5	2/12/2003	0.64	2.56	0.61	2.62			0.13	0.60
6	2/25/2003	1.94	2.93	0.82	2.83	1.00	1.69	0.92	1.41
7	10/27/2004	1.50	3.01	0.96	2.07	0.41	2.00	4.13	3.80
8	1/12/2005	1.47	2.95	1.35	2.05			0.16	0.98
9	3/23/2005	0.78	1.32	0.44	2.68			0.11	0.58
10	2/28/2006	0.69	2.82	0.37	2.36				
11	4/5/2006	0.32	1.80	0.62	2.49				
12	1/5/2008							0.39	1.15
13	1/27/2008	0.58	1.90	1.08	2.70	0.46	1.82	1.22	4.00
13	2/4/2008							0.43	1.03
14	11/26/2008	1.51	3.07	0.77	1.57				
15	2/16/2009	0.68	2.08	1.32	3.65	0.45	1.49		
16	12/12/2009	0.46	1.94	0.61	2.70				
17	1/20/2010	1.12	2.13	0.99	2.33	0.58	1.95	10.13	7.09
18	2/5/2010	1.12	3.81	0.77	2.20	0.80	2.43		
19	12/21/2010	0.72	2.01			0.46	1.56		
20	2/18/2011	1.87	3.60	0.42	2.81	0.56	1.38		
21	2/25/2011	4.19	3.56	0.54	2.11	0.94	2.21		
22	3/17/2012	0.94	2.56	0.33	2.12				
23	3/26/2012	0.26	1.85	0.23	1.73				
24	4/26/2012	0.56	2.58	0.41	2.18				
25	2/20/2013	0.73	2.39	0.30	2.11				
26	3/8/2013	0.56	2.57	0.33	1.70				
27	2/28/2014	0.85	2.16	1.15	3.32				
Median of all Samples		0.71	2.58	0.54	2.49	0.51	1.89	0.32	0.92

Median event nutrient concentrations (C_{median}) from the two inputs to Canyon Lake (Salt Creek and San Jacinto River) and overflow to Lake Elsinore, when active, are shown in Table 4-6. Use of a flow-weighted average was considered but not used because no significant relationship was found between flow rate and nutrient concentration when comparing events. The median values were applied to annual volumes measured at the USGS gauges to estimate loading to the lakes from most of the watershed, as follows:

$$L_{annual} = Q_{annual} * C_{median}$$

Figures 4-13 and 4-14 show estimated annual nutrient loads based on measurements of daily flow and average of water quality monitoring data. The estimated retention of nutrient loads within Canyon Lake is computed from measured data similarly to volume retention (see Figure 4-1 above). Retained nutrient loads are estimated as the difference between the summed annual loading for stations upstream and downstream of Canyon Lake for years when Canyon Lake elevation data exceeded its spill water elevation of 1381.76 ft (2003-05, 2008, and 2010-11), indicating that overflows occurred. In dry years when the lake did not overflow, all nutrients loads are assumed to be retained.

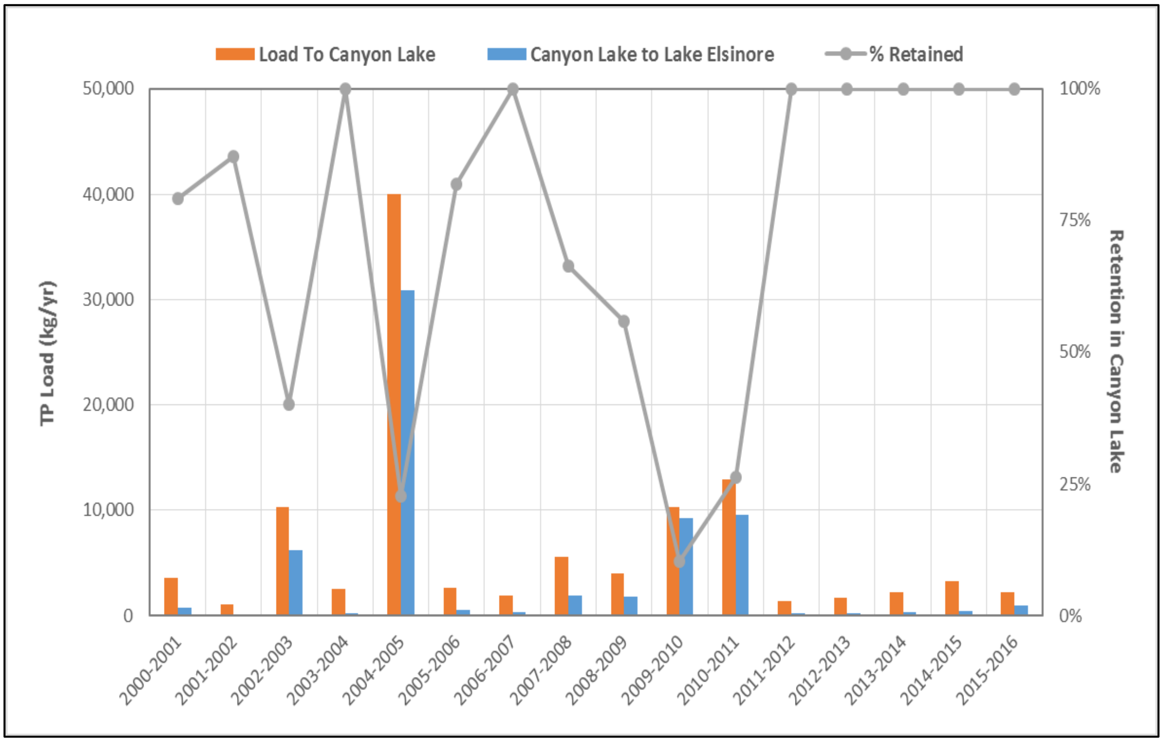

Figure 4-13

Annual Total Phosphorus Load into Canyon Lake and Overflow to Lake Elsinore

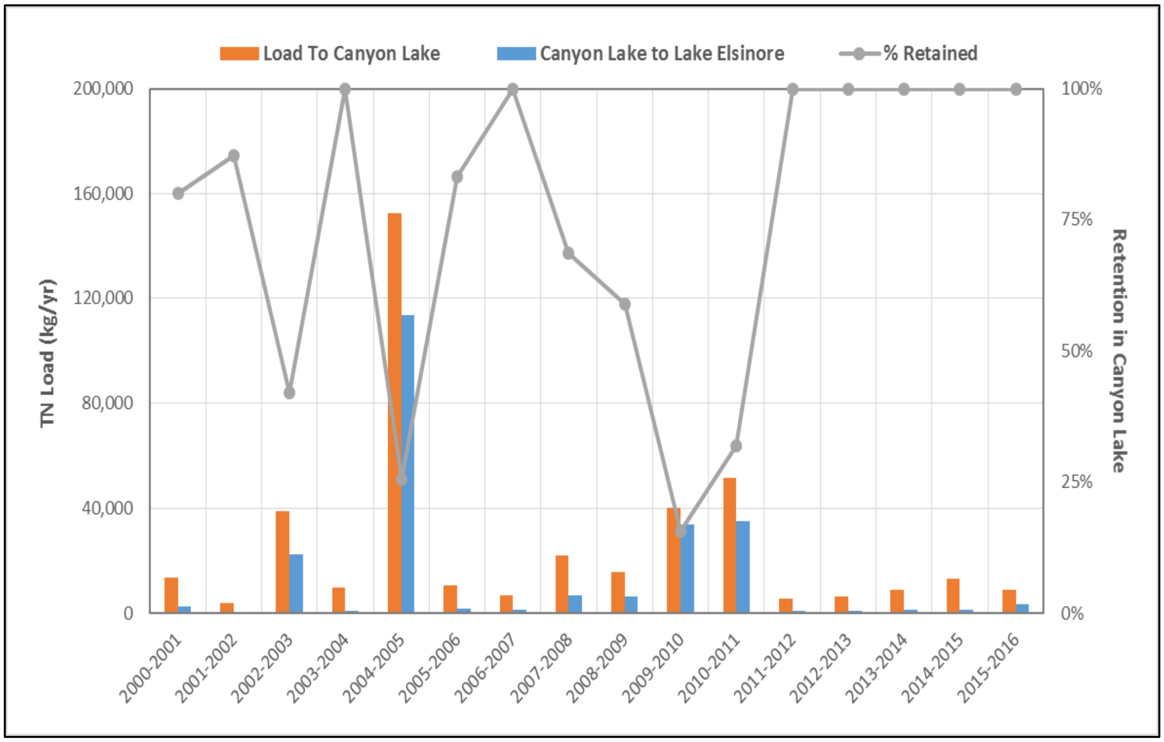

Figure 4-14

Annual Total Nitrogen Load into Canyon Lake and Overflow to Lake Elsinore

4.1.4.3 Nutrient Washoff Model

PLOAD was employed to estimate nutrient washoff to downstream lake segments. This method computes downstream annual nutrient loads (L_{annual}) as a function of average annual runoff (Q_{annual}) and event mean concentrations (EMCs)[12] for spatially lumped subareas with common land use (LU), subwatershed zone (Z), and jurisdiction (J), as follows:

$$L_{annual} = \sum_{LU,Z,J} Q_{annual} * EMC_{LU}$$

Thus, the estimation of nutrient loads delivered to downstream lake segments is based on hydrologic model results and assumed values for total phosphorus and total nitrogen EMCs in washoff from general land use categories. Table 4-7 presents the land use-based EMCs used to develop the source assessment for the TMDL revision. Table 4-7 also documents the monitoring data from sites in the vicinity of the San Jacinto River watershed that served as the basis for each of these EMCs. These monitoring sites are representative of the general land use categories (Figure 4-15). Generally, urban land use groups were characterized from NPDES monitoring conducted by RCFC&WCD at core monitoring sites[13] and agricultural land use groups were characterized by a special study of cropland plot scale nutrient BMP

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[12] An event mean concentration (EMC) is the average concentration of a water quality parameter over the course of an entire wet weather event. The average of EMCs from multiple sampled events provides a more robust estimate of the central tendency for the upstream drainage area

[13] RCFC&WCD (2015). Report of Waste Discharge

effectiveness conducted by UC Riverside[14] through a 319(h) grant. In addition, the National Stormwater Quality Database (NSQD)[15] contained data from multiple sites from freeways in the vicinity of the SJR watershed that were used to characterize transportation land use in the watershed. Lastly, EMCs for Pasture / Hay / Ranch and Other Livestock land use groups have not been published from studies in the watershed vicinity. Estimated EMCs for pasture land cover for Central Florida was synthesized in H.H. Harper (1998)[16] and is used for this source assessment. These two land use groups compromise approximately 1 percent of the total acreage in the drainage areas to the lakes based on mapping completed in 2014 (see Table 4-5 above), therefore values for these EMCs are relatively insensitive to the estimate of downstream loads.

Table 4-7. Land Use Specific Event Mean Concentrations used for Source Assessment

Land Use	TP (mg/L)	TN (mg/L)	Site Name	Source (number of samples; period of record)
Commercial / Industrial	0.54	3.89	Corona Storm Drain (Sta 40)	RCFC&WCD (n=30; 2004 – 2014)
Residential - Sewer	0.48	2.93	Sunnymead Channel (Sta 316)	RCFC&WCD (n=30; 2004 – 2015)
Residential - Septic	0.59	5.30	Canyon Lake at Sierra Park (Sta 834)	RCFC&WCD (n=21; 2000-2004)
Roadway	0.31	4.88	Freeway (FW) CACTA006, 011, 012, 013	NSQD (n=14; 1997 - 1999)
Irrigated Cropland	1.04	4.08	Pumpkin Control	UC Riverside (n=8; 2008)
Non-Irrigated Cropland	1.21	3.25	Wheat Control	UC Riverside (n=14; 2007-2009)
Orchards / Vineyards	1.13	1.71	Citrus Control	UC Riverside (n=17; 2007 – 2009)
Open Space / Forested	0.32	0.92	Cranston Guard Station	US Forest Service (n=54; 2001 – 2010)
Pasture / Other Livestock	0.48	2.48	Not reported	Harper, H.H. 1998

1) No EMCs were applied for dairy land uses based on presumed compliance with CAFO Permit requirement for on-site runoff retention up to 25 year return period storm event.

The RCFC&WCD monitoring site at Canyon Lake at Sierra Park is located downstream of Quail Valley, a low density residential area that was not historically serviced by any centralized sewer system. A large project to bring sewer service to this area is currently underway. Monitoring at the downstream sample site was conducted prior to any sewer construction and therefore may be representative of residential land use with on-site sanitary treatment and disposal systems (OSTDS), referred to as septic systems in this report. The nutrient concentration data from this site show similar TP levels to sewered residential but roughly 80 percent greater TN concentration. This difference makes sense given that adsorption of nitrogen in soils is less efficient than phosphorus. A similar water quality response was observed from a smaller sample set collected from Meadow Brook, a tributary to the San Jacinto River just above the

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[14] University of California at Riverside. Assessment of Best Management Practices to Reduce Nutrient Loads. Final Report for Section 319(h) Grant, Agreement No 05-040-558-1 between the State Water Resources Control Board and Regents of the University of California, 2011.

[15] http://www.bmpdatabase.org/nsqd.html

[16] Harper, H.H. (1998). Stormwater Chemistry and Water Quality. http://www.erd.org/ERD%20Publications/STORMWATER%20CHEMISTRY%20AND%20WATER%20QUALITY---1999.pdf

inflow to Canyon Lake Main Lake, with elevated TN concentrations averaging over 10 mg/L (see Attachment B of the CNRP)[17].

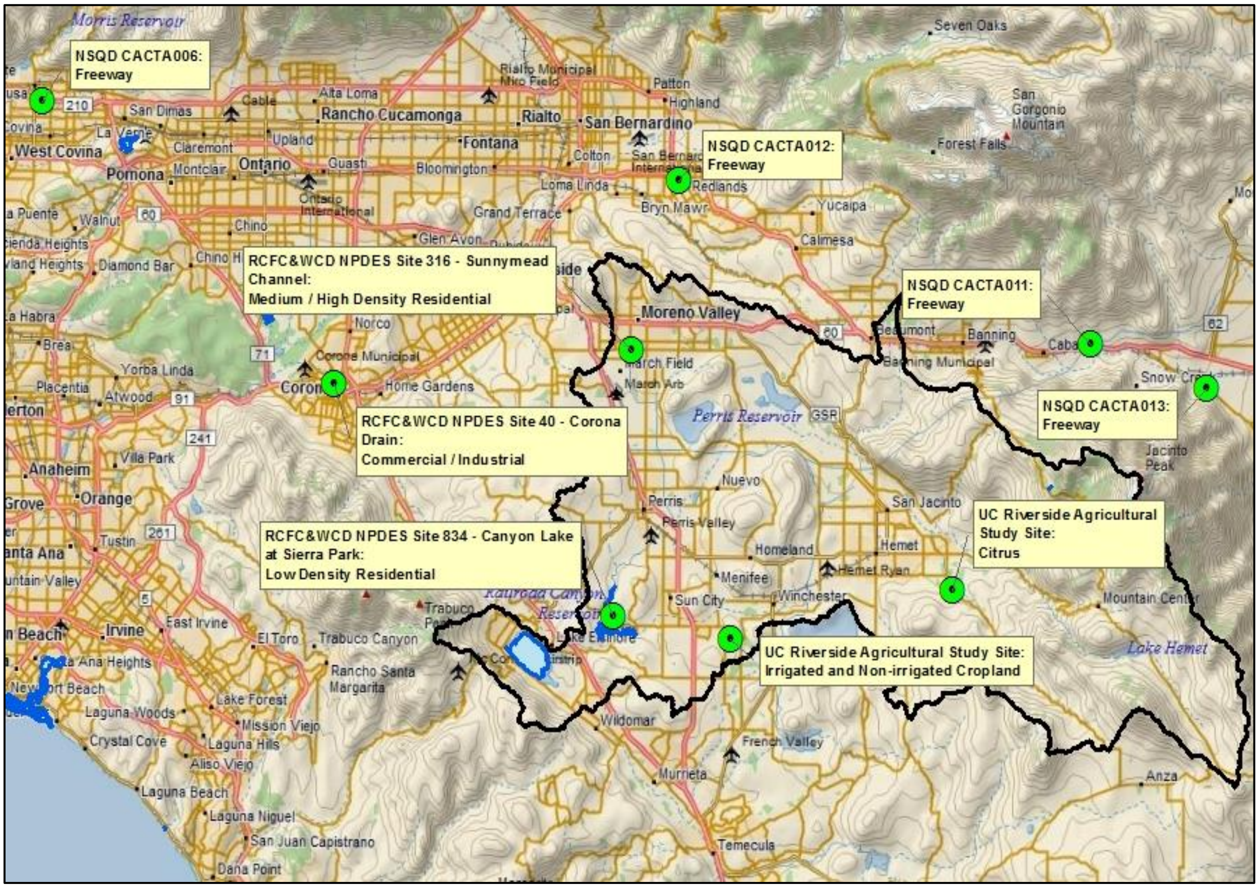

Figure 4-15
Map of showing water quality monitoring sites in the San Jacinto River watershed and vicinity used to estimate land use based EMCs for TP and TN

Both Quail Valley and Meadow Brook are situated over portions of the watershed with shallow (<2 meters) depths to bedrock, thereby posing a greater risk of short-circuiting septic leachfields during wet weather events. A review of regional SSURGO soil survey mapping[18] showed that most other residential – septic model subareas (displayed in Figure 4-2 above) in the watersheds to Canyon Lake and Lake Elsinore also overlay areas with shallow depth to bedrock. Thus, the TMDL revision applied an EMC specifically for model subareas identified as residential – septic to account for nutrients from potentially failing septic systems watershed-wide. This approach differs from the method in the 2004 TMDL source assessment, which involved a separate loading analysis to attempt to quantify nutrient loads in potentially failing septic systems. The previously employed approach required rough assumptions about failure rates and how wet weather conditions mobilize incompletely treated sewage.

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[17] CDM Smith (2013). Comprehensive Nutrient Reduction Plan for MS4 Permittees in the Canyon Lake and Lake Elsinore Nutrient TMDL, http://www.sawpa.org/wp-content/uploads/2012/05/CNRP-for-Lake-Elsinore-and-Canyon-Lake_Final.pdf

[18] http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

For each referenced monitoring station, the median of collected wet weather samples was computed and served as the EMC value in the source assessment model. The full range of wet weather TP and TN concentrations are plotted as box/whisker plots in Figure 4-16 for TP and Figure 4-17 for TN. These plots show the median (black line through box), 25th and 75th percentiles (lower and upper bounds of box) and minimum and maximum values (whiskers) for the full dataset.

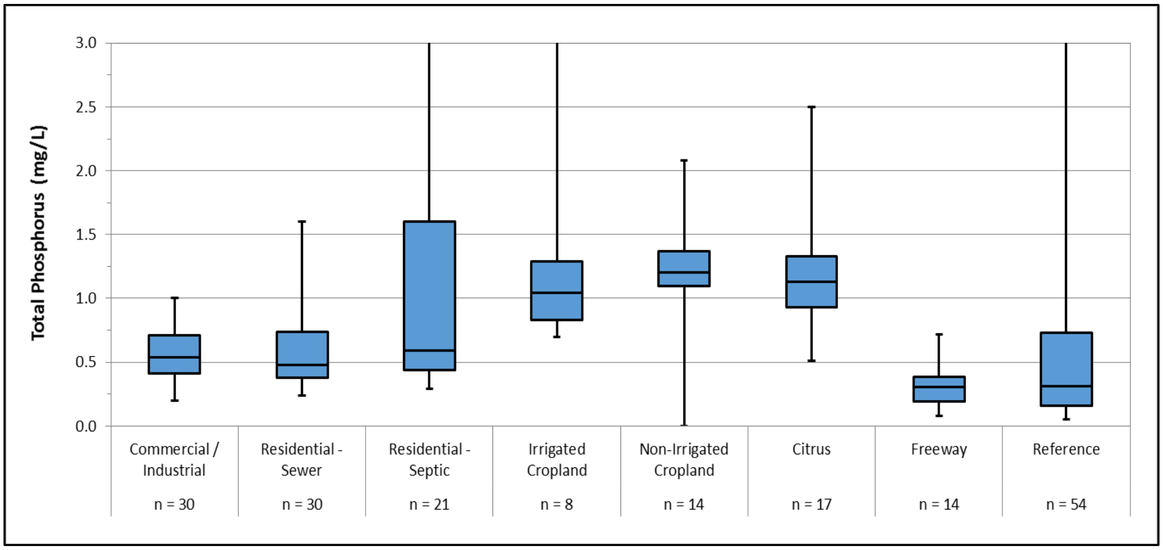

Figure 4-16
Box/whisker plots of wet weather TP from land use specific EMC sites (data for Other Livestock or Pasture/Hay/Ranch land uses not available)

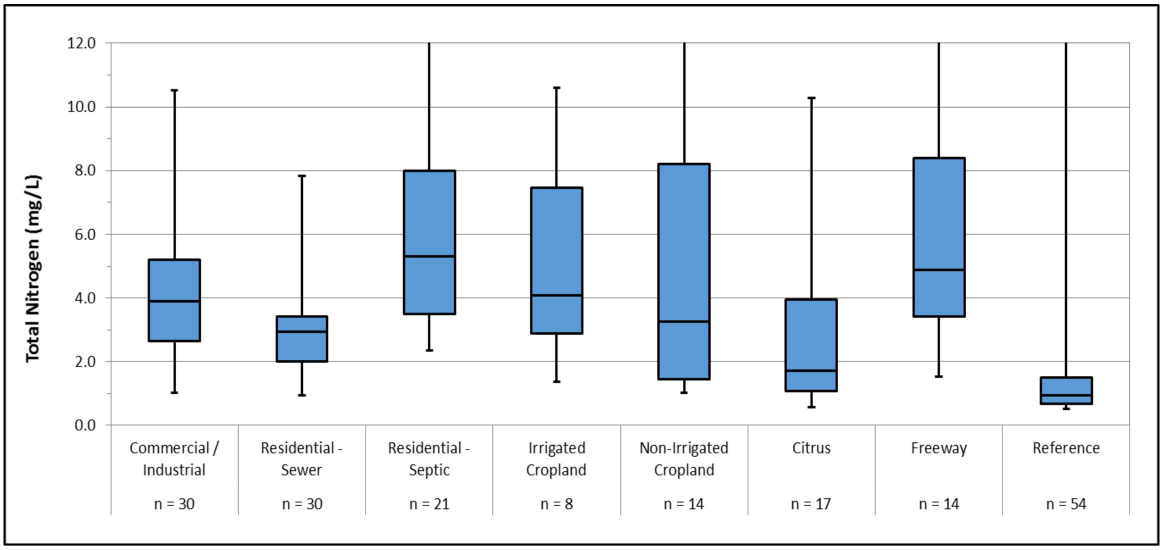

Figure 4-17
Box/whisker plots of wet weather TN from land use specific EMC sites (data for Other Livestock or Pasture/Hay/Ranch land uses not available)

Applying these land use specific EMCs to average annual runoff (see Section 4.1.2 above) provides an estimate of nutrient loads for all model subareas. Taking only model subareas from upstream of USGS gauges on San Jacinto River at Goetz Road and Salt Creek at Murrieta Road and simulating average annual rainfall for the period of 2000-2016 allows for comparison of modeled to measured loads (Figure 4-18). Ungauged subareas that are downstream of the monitoring sites and drain directly to the shoreline of Canyon Lake (see Figure 4-11 above) as well as all model subareas upstream of Mystic Lake (no overflows occurred in 2000-2015 period) are excluded from these outputs.

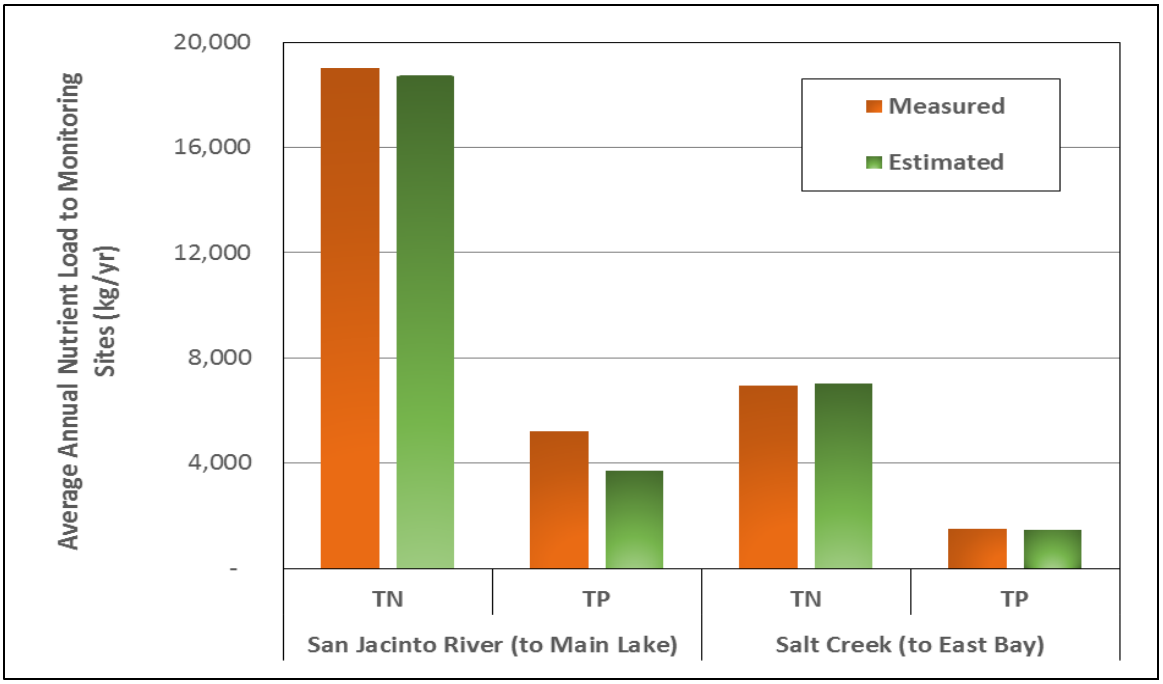

Figure 4-18
Comparison of modeled and estimated average (2000-2016) annual nutrient loads to monitoring sites for San Jacinto River at Goetz Road and Salt Creek at Murrieta Road

Generally, the model performed well in predicting average annual nutrient loads when compared with estimated loads from measured data at the two downstream monitoring sites. No changes were made to the land use based EMCs that were determined from medians of TN and TP concentration from select monitoring stations with a predominant upstream land use category (see Table 4-7 above). The model did slightly under-predict annual TP loads to the San Jacinto River at Goetz Road. It is possible that another in-stream source is present in this drainage area to account for elevated concentrations (median TP of 0.71 mg/L) at the downstream station.

Results for nutrients loads delivered to the lake segments based on long-term average annual rainfall (1948-2015) and accounting for all model subareas are reported in Table 4-8. The results in Table 4-8 include the overflows from Canyon Lake to Lake Elsinore and overflows from Mystic Lake to the San Jacinto River and ultimately the Main Lake of Canyon Lake.

Table 4-8. Model Results for Long-Term Average (1948-2016) Annual Runoff and Nutrient Load Delivered to Lake Segments

Receiving Lake Segment	Runoff Inflow (AFY)	TP (kg/yr)	TN (kg/yr)
Canyon Lake Main Lake[1]	10,975	5,007	23,540
Canyon Lake East Bay	3,768	1,516	7,397
Lake Elsinore[2]	9,530	5,037	19,931

1) Includes estimated Mystic Lake average annual overflow volume (accounting for zero years) and associated nutrient loads from subwatershed 7-9

2) Includes measured overflow volume from Canyon Lake to Lake Elsinore shown in Figure 4-1 and estimated loads based on medians of historical watershed monitoring data shown in Table 4-6 (median TP = 0.51 mg/L; TN = 1.89 mg/L)

Nutrient loading to lake segments from watershed runoff are summarized by subwatershed zone and by general land use category in Figures 4-19 and 4-20, respectively. Results show the greatest loading of nutrients originates in subwatershed zone 5, which comprises the entire drainage area of Perris Valley Channel. Nutrient loads from Zone 4 that are estimated to reach Canyon Lake East Bay are approximately half of washoff from model subareas as a result of significant channel bottom recharge in Salt Creek.

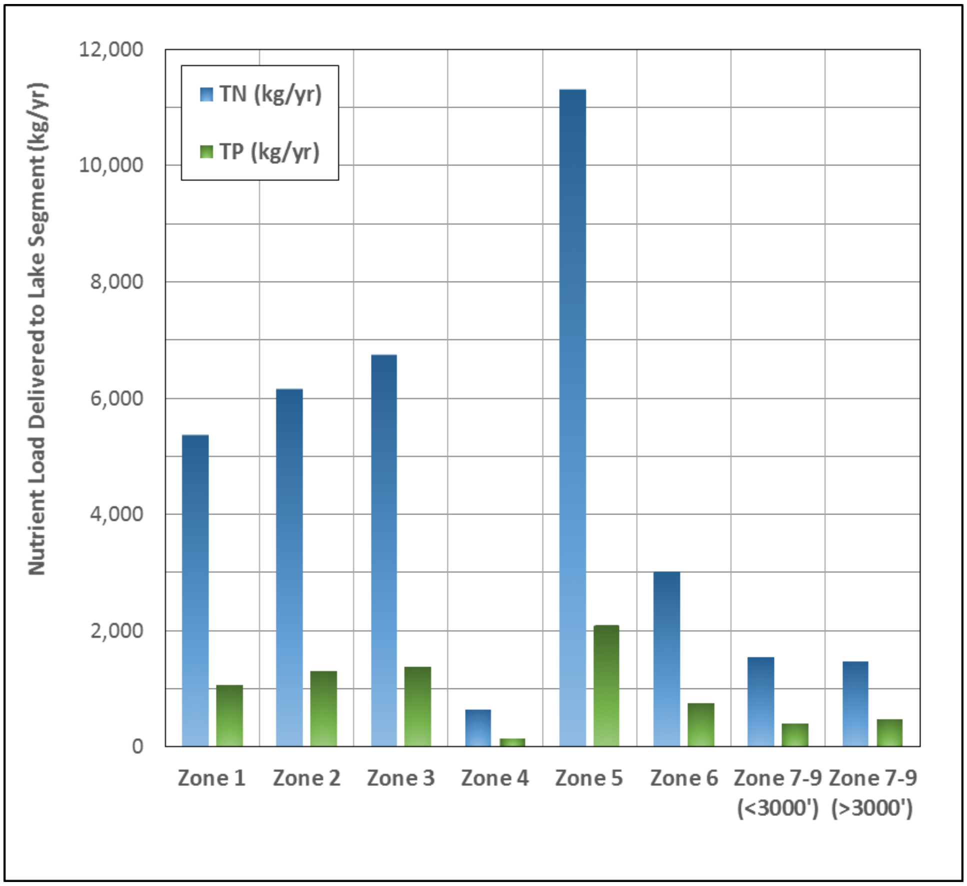

Figure 4-19
Nutrient loading to lake segments by subwatershed zone

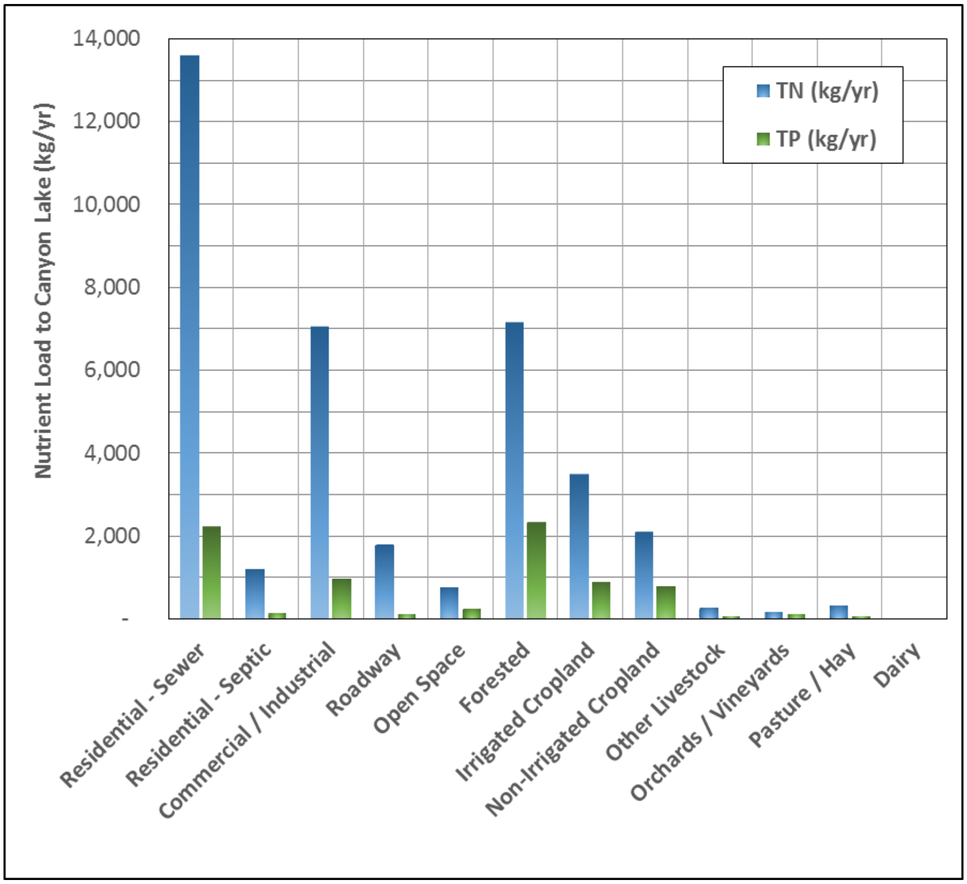

Figure 4-20
Nutrient loading to lake segments by general land use category

Land use categories with the greatest acreage in the watershed were the largest source of nutrient loading to the lake segments. This includes residential – sewered and commercial / industrial categories as well as forest and open space model subareas. Agricultural land uses in the San Jacinto River watershed have declined significantly since the existing TMDLs were developed. Despite having relatively higher EMCs, the lower imperviousness and reduction of total agricultural acreage has reduced the source contribution from agricultural land use categories to the lake segments relative to the 2004 TMDL.

4.2 Supplemental Water

An additional source of volume and nutrient load exists for Lake Elsinore in the form of reclaimed wastewater from Elsinore Valley Municipal Water District's (EVMWD's) regional water reclamation facility (RWRF). Since 2008, EVMWD has added reclaimed wastewater to Lake Elsinore for lake level stabilization. A deeper lake provides multiple benefits including aesthetics, recreational use, and water quality. EVMWD's NPDES permit (R8-2013-0017, NPDES No. CA8000027) for this discharge to Lake Elsinore includes requirements for nutrient loads to the lake as follows:

- Total Nitrogen - 12-month running average TN concentration shall not exceed 1 mg/L, and the 5 year running average mass of TN discharged to the Lake shall not exceed 16,372 pounds/year

(7,442 kg/yr), unless the discharger implements a plan, with the approval of the Regional Water Board or its Executive Officer, to offset TN discharges in excess of the TN limits.

- Total Phosphorus - 12-month running average TP concentration shall not exceed 0.5 mg/L, and the 5 year running average mass limit for TP discharged to the Lake shall not exceed 8,186 pounds/year (3,721 kg/yr), unless the discharger implements a plan, with the approval of the Regional Water Board or its Executive Officer, to offset TN discharges in excess of the TN limits.

The annual volumes of reclaimed water discharged and estimated total phosphorus and total nitrogen loads are reported in Table 4-8. The estimated load is based on an average annual concentration in effluent from 2014-2016 of 0.37 mg/L TP and 2.83 mg/L TN. Current treatment mechanisms at the RWRF reduce TP to meet the limit concentration of 0.5 mg/L. Conversely, typical TN concentrations exceed the allowable concentration of 1.0 mg/L. Therefore, EVMWD uses nitrogen offset credits accrued by operation of the LEAMS to meet the permit requirements. In years when there is little or no overflow from Canyon Lake, the discharge of reclaimed water to maintain lake levels is the largest source of new external nutrient loads to Lake Elsinore.

Table 4-8. Volume and Estimated Nutrient Load in Supplemental Water Additions to Lake Elsinore

Year	Reclaimed Water (AFY)	Island Wells (AFY	Total Supplemental Volume (AFY)	Estimated TP Load (kg/yr)	Estimated TN Load (kg/yr)
2007	2,361		2,361	1070	8267
2008	5,365	359	5,724	2434	19357
2009	5,470	404	5,874	2485	19736
2010	6,039	385	6,425	2743	21792
2011	1,920	6	1,925	872	6926
2012	5,499	295	5,794	2507	19843
2013	5,843	264	6,106	2670	21698
2014	5,778	298	6,075	2651	21458
2015	1,930	50	1,981	891	7169
2007-2015 Average	4,467	258	4,696	2,036	16,250

4.3 Internal Sources

Several sources of nutrients result from processes that happen within the lake ecosystem, including sediment nutrient flux and atmospheric deposition. The following sections describe these processes and estimates associated nutrient loads.

4.3.1 Sediment Nutrient Flux

Nutrients that settle to the bottoms of Canyon Lake and Lake Elsinore bound to organic matter or otherwise particle bound are not immediately available for phytoplankton uptake. Instead these nutrients undergo processes within the lake bottom to move from bound to more soluble forms (PO_4 and NH_4) referred to as diagenesis. Anoxic conditions in the lake bottom sediments increase the rate of digenesis by chemical reduction of iron bound phosphorus to a loosely bound ferrous form and by allowing for anaerobic bacterial decomposition of organic matter in sediments releasing ammonia into pore waters. Flux of these solubilized forms from the lake bottom across the sediment-water interface to the water column occurs by diffusion and physical resuspension.

4.3.1.1 Canyon Lake

Rates of nutrient flux from bottom sediment to the water column vary across Canyon Lake based upon bathymetry and relationship to inflows, and are further influenced by temperature and DO concentration. Based upon core-flux measurements made at a small number of sites (Anderson, 2003), bathymetric survey results and hydroacoustic signature of the sediments, estimates of sediment nutrient flux rates were developed across the lake. Core-flux measurements indicated a modest positive increase in NH_4-N flux with water depth, while PO_4-P typically exhibited greater flux rates in shallower water, e.g., in East Bay where significant deposition of silt eroded from the watershed are typically deposited. Based upon these considerations, nominal flux rates across the lake for NH_4-N and PO_4-P were used in model simulations, shown in Figures 4-21 and 4-22, respectively.

Sediment nutrient flux rates in ELCOM-CAEDYM were specified at standard temperature and DO conditions for each bottom cell within the computational domain; the flux rate was then corrected for the temperature and DO condition present at each model time-step (Hipsey, 2014).

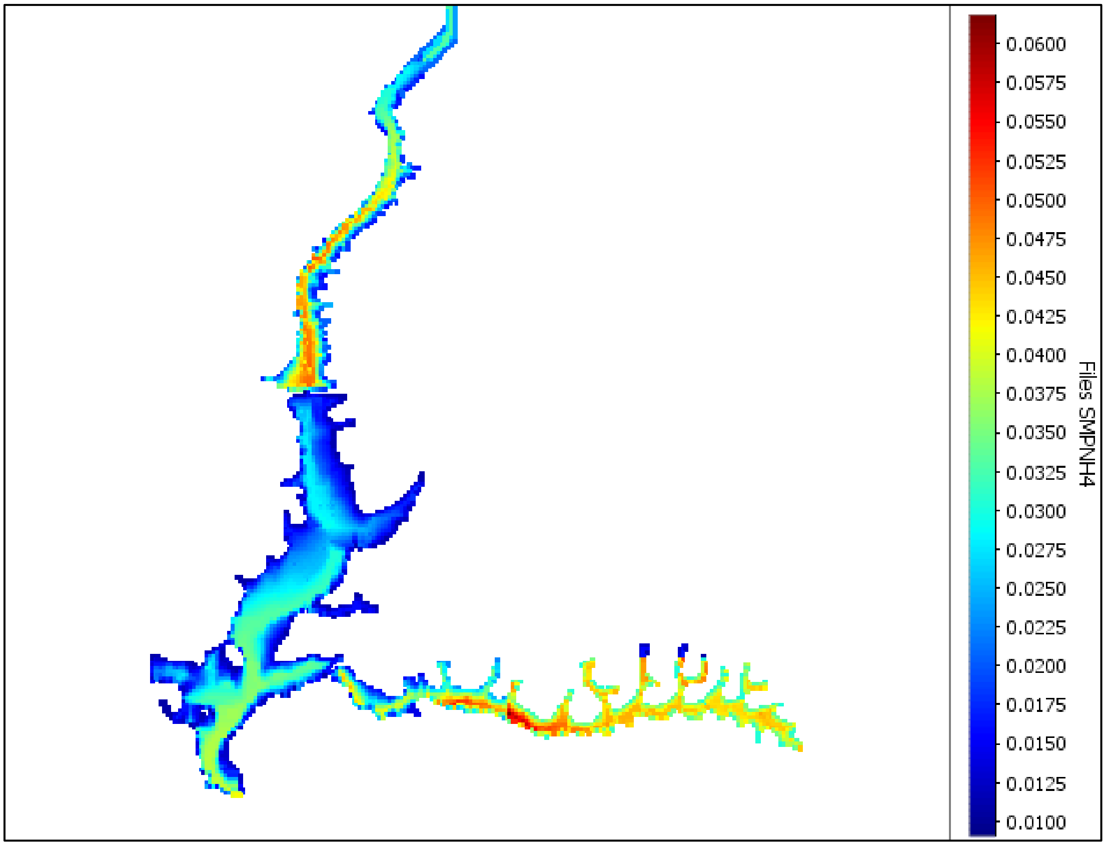

Figure 4-21
Modeled flux rate (g/m^2/day) of NH_4-N from Canyon Lake bottom sediment to overlying water column

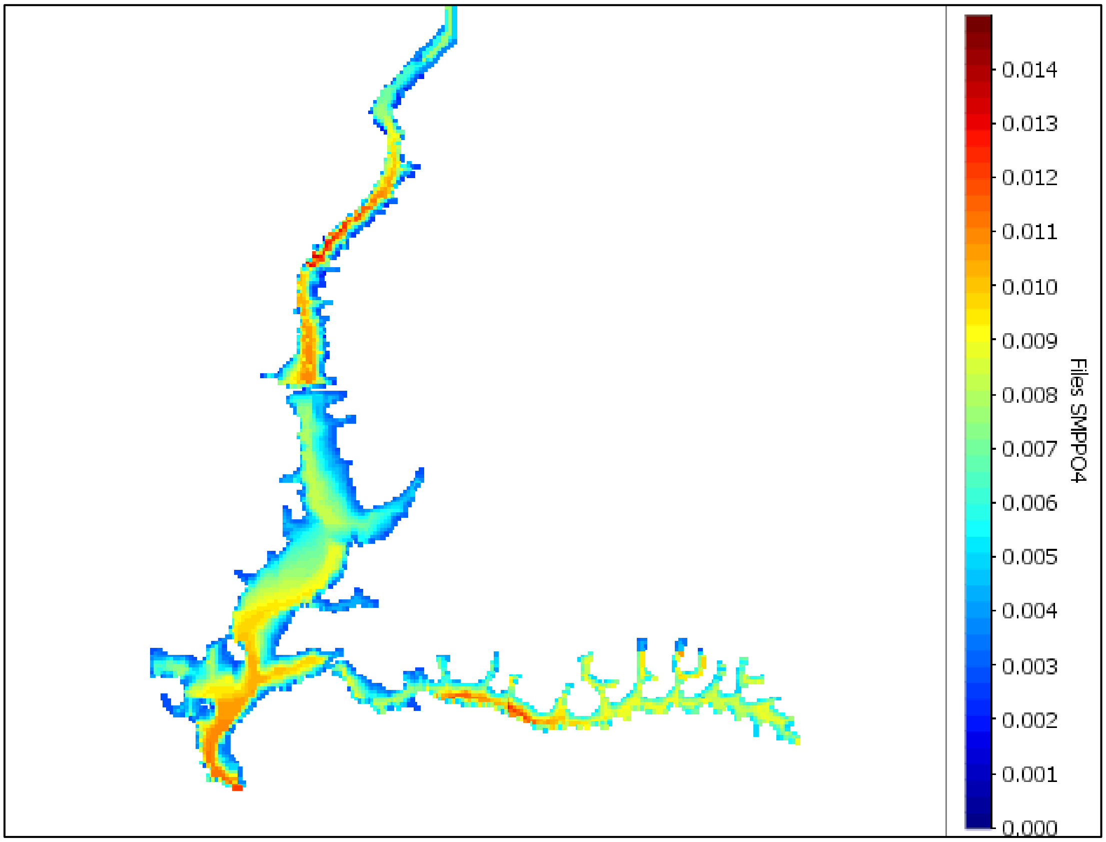

Figure 4-22
Modeled flux rate (g/m^2/day) of PO_4-P from Canyon Lake bottom sediment to overlying water column

The average nominal flux rate for NH_4-N calculated from Figure 4-21 is 28.5 mg/m^2/day, corresponding to a daily NH_4-N flux of 53.8 kg/day or 19,626 kg/year for the entire 464 acres of simulated lake bottom area. This represents an increase of 6,077 kg/yr over the estimated flux in the 2004 TMDL. The increase is most likely attributed to the larger bottom area involved in the lake water quality model simulation (464 acres compared with 300 acres). For PO_4-P flux, the estimated rate was 6.9 mg/m^2/d corresponding to an annual average load of 4,724 kg/yr. This load is very close to the load estimated for the 2004 TMDL despite the increased bottom area considered.

4.3.1.2 Lake Elsinore

The 1-D approximation used for modeling of Lake Elsinore necessitates use of average internal loading rates for NH_4-N and PO_4-P across the lake, modulated by temperature and DO as described above. That is, based upon depth-area-volume information provided for the lake and dynamically simulated lake level, temperature and DO concentration with depth, nutrient flux rates are apportioned to allow for the fraction of the bottom sediments that are shallow, warm and generally well-aerated to release nutrients at a rate that is potentially quite different than deeper anoxic sediments. The nominal PO_4-P flux rate was taken as 8 mg/m$_2$/d while the nominal NH_4-N flux rate was taken as 80 mg/m^2/d based upon core-flux measurements (Anderson 2002). Assuming a lake area of approximately 3000 acres, this corresponds to annual PO_4-P and NH_4-N inputs to the water column of 35,452 kg and 354,520 kg, respectively.

4.3.2 Atmospheric Deposition

Nutrients within air overlying the surface of the lakes settle onto the lake surface and act as a small source of nutrients to the lakes. This source of nutrients to Canyon Lake and Lake Elsinore has not been re-evaluated since the 2004 TMDL, thus the same estimates are used in this revision. A brief summary is provided below.

Studies by Anderson (2001) [19] for Lake Elsinore and Anderson and Oza (2003) [20] for Canyon Lake estimated atmospheric deposition as part of a nutrient budget analysis. Irrespective of the amount of precipitation in a given year, these studies estimated atmospheric deposition of nutrients to be very small relative to the total nutrient budget, therefore average atmospheric deposition rates for nitrogen and phosphorus from these studies were used without adjusting for precipitation for individual years. Table 4-9 presents the estimated nutrient loads from atmospheric deposition to Canyon Lake and Lake Elsinore reported in these studies and incorporated into the 2004 TMDL source assessment.

Table 4-9. Estimated Nutrient Loads from Atmospheric Deposition onto Surface of Canyon Lake and Lake Elsinore

Lake Segment	Estimated TP Load (kg/yr)	Estimated TN Load (kg/yr)
Canyon Lake – Main Lake	144	1,253
Canyon Lake – East Bay	77	665
Lake Elsinore	108	11,702

4.4 Summary of Nutrient Sources

There are a several key sources of nutrients to Canyon Lake, Main Lake and East Bay, and Lake Elsinore. These sources vary seasonally and according to inter-annual climate patters in their relative importance to water column nutrients. This source assessment describes the individual sources and quantifies long-term average loading of nutrients to each lake segment. Table 4-10 presents a summary of all the general nutrient source categories for each lake segment. The relative contribution of each category is also shown as pie charts for Lake Elsinore in Figure 4-23, Canyon Lake Main Lake in Figure 4-24, and Canyon Lake East Bay in Figure 4-25.

Table 4-10. Summary of Nutrient Loads from All General Source Categories

General Source Category	Canyon Lake Main Lake		Canyon Lake East Bay		Lake Elsinore	
	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)	TP (kg/yr)	TN (kg/yr)
Watershed Runoff	6,160	29,065	2,109	10,105	5,222	20,898
Sediment Nutrient Flux	3,668	15,237	1,056	4,389	35,452	354,520
Atmospheric Deposition	144	1253	77	665	108	11,702
Supplemental Water	n/a	n/a	n/a	n/a	2,036	16,250
Total Average Annual Loading	9,972	45,555	3,242	15,160	42,818	403,370

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[19] Anderson, M.A. 2001. Internal Loading and Nutrient Cycling in Lake Elsinore. Final report submitted to Santa Ana Regional Water Quality Control Board.

[20] Anderson, M.A. and Oza, H. 2003. Internal Loading and Nutrient Cycling in Canyon Lake. Final report submitted to Santa Ana Regional Water Quality Control Board

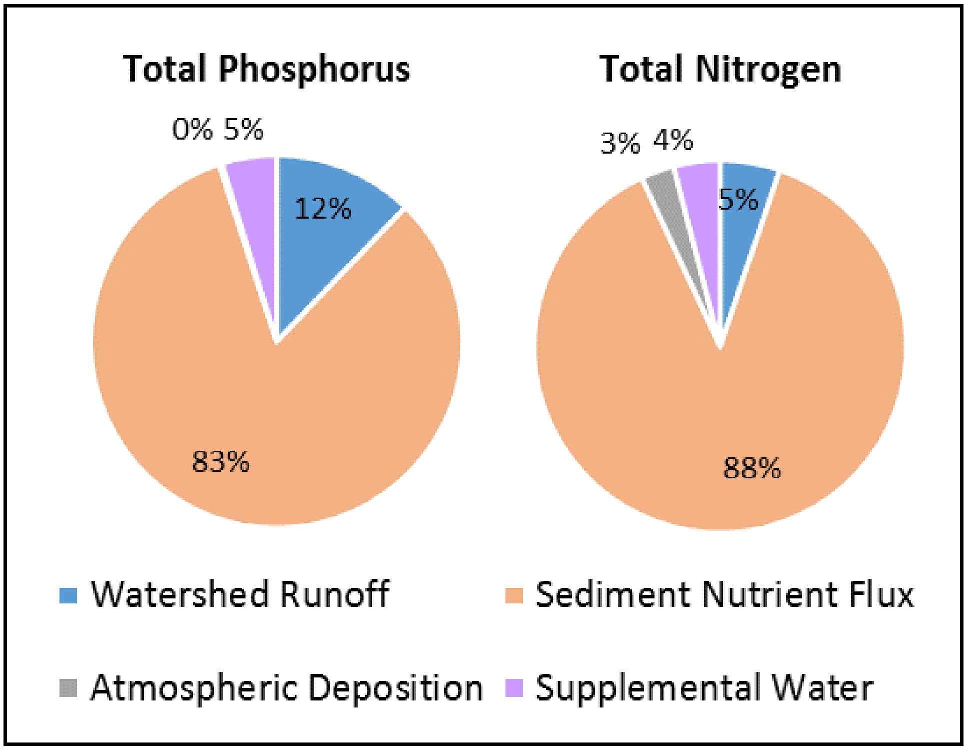

Figure 4-23
Relative contribution of general source categories for Lake Elsinore long-term average annual nutrient budget

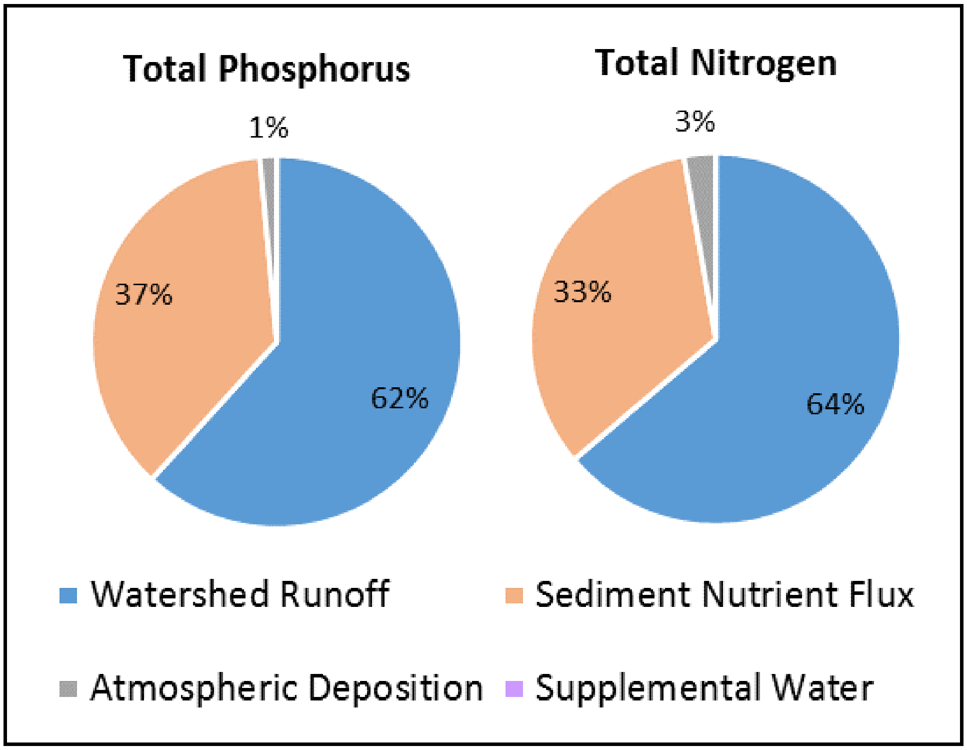

Figure 4-24
Relative contribution of general source categories for Canyon Lake Main Lake long-term average annual nutrient budget

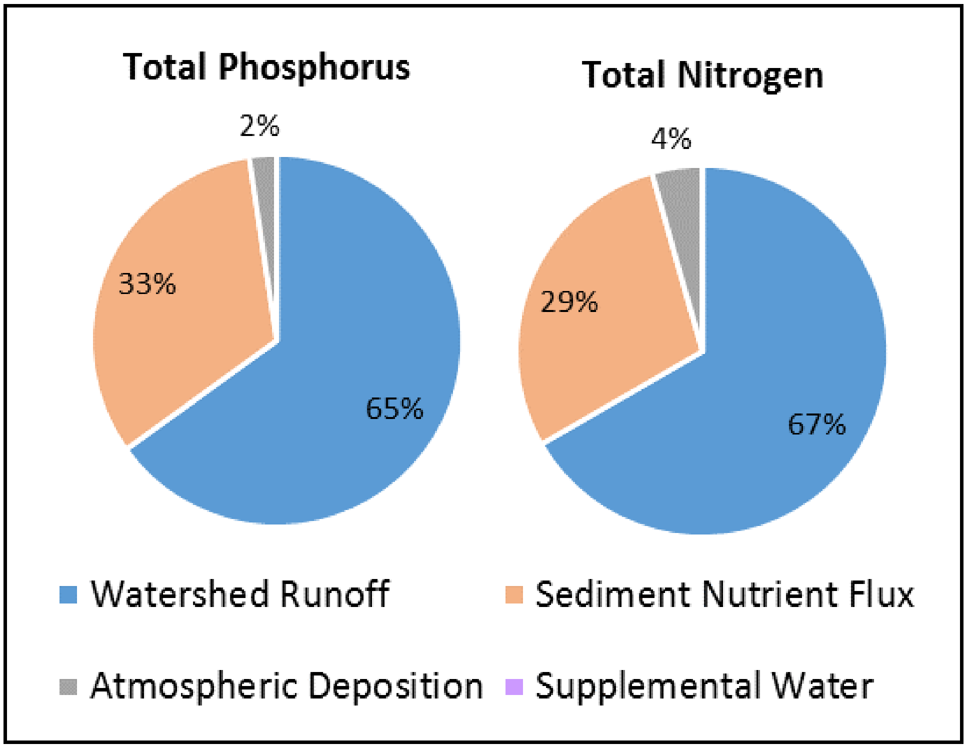

Figure 4-25
Relative contribution of general source categories for Canyon Lake East Bay long-term average annual nutrient budget

The single most apparent finding when reviewing the relative source contributions shown in Figures 4-23 through 4-25 is that internal loads in the form of sediment nutrient flux dominate the long-term nutrient budget for Lake Elsinore, while external loads play a much greater role in the nutrient budgets for Canyon Lake, both in Main Lake and East Bay. This finding has profound consequences for developing compliance milestones and in specifying the most effective implementation approaches for each lake segment.

Recall the basis for setting numeric targets is to create a water quality condition that is equal to or better than what may occur without anthropogenic impacts in the San Jacinto River watershed. This chapter quantifies nutrient sources for the existing developed condition; however, the same general categories of nutrient sources would exist in a reference, or pre-developed, watershed condition. The incremental increase in the combined nutrient loads from a reference watershed to what is quantified in this source assessment represents the reductions that will be required and the basis for setting allocations, as described in the following chapter.